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Bulletin
of
The Geological Society of America

VOLUME 59 February 1948 NUMBER 2

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CENTRAL KANE COUNTY, UTAH: A GEOGRAPHIC AND GEOLOGICAL RECONNAISSANCE. By H. E. Gregory

GEOLOGY OF THE TECOPA AREA, SOUTHEASTERN CALIFORNIA. By John Mason

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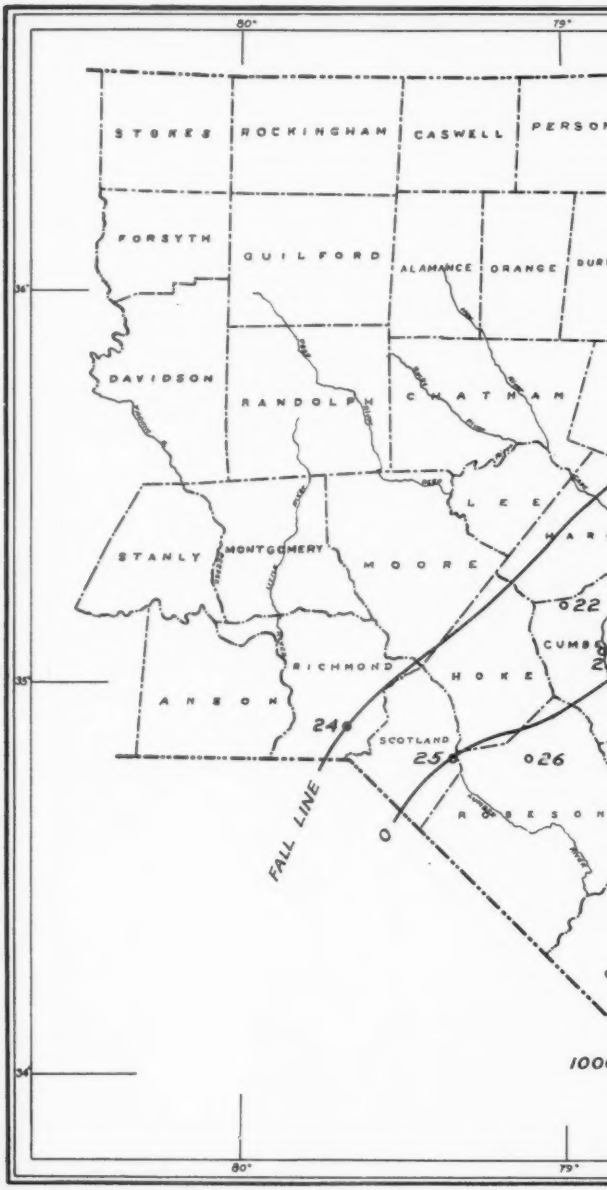

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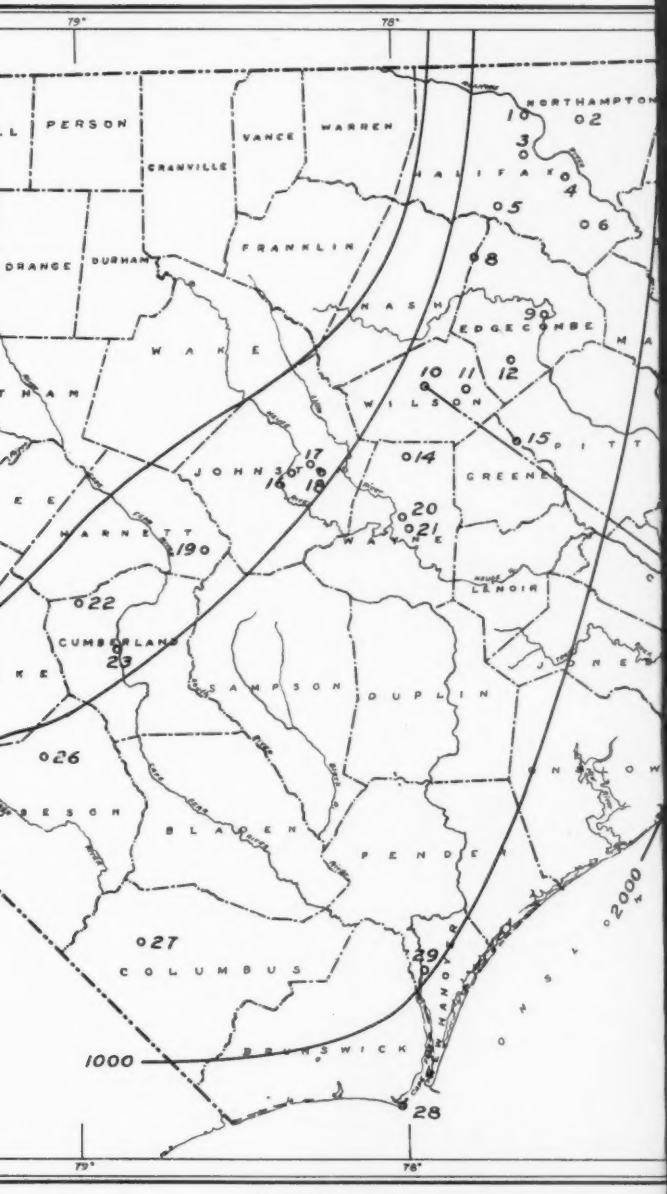

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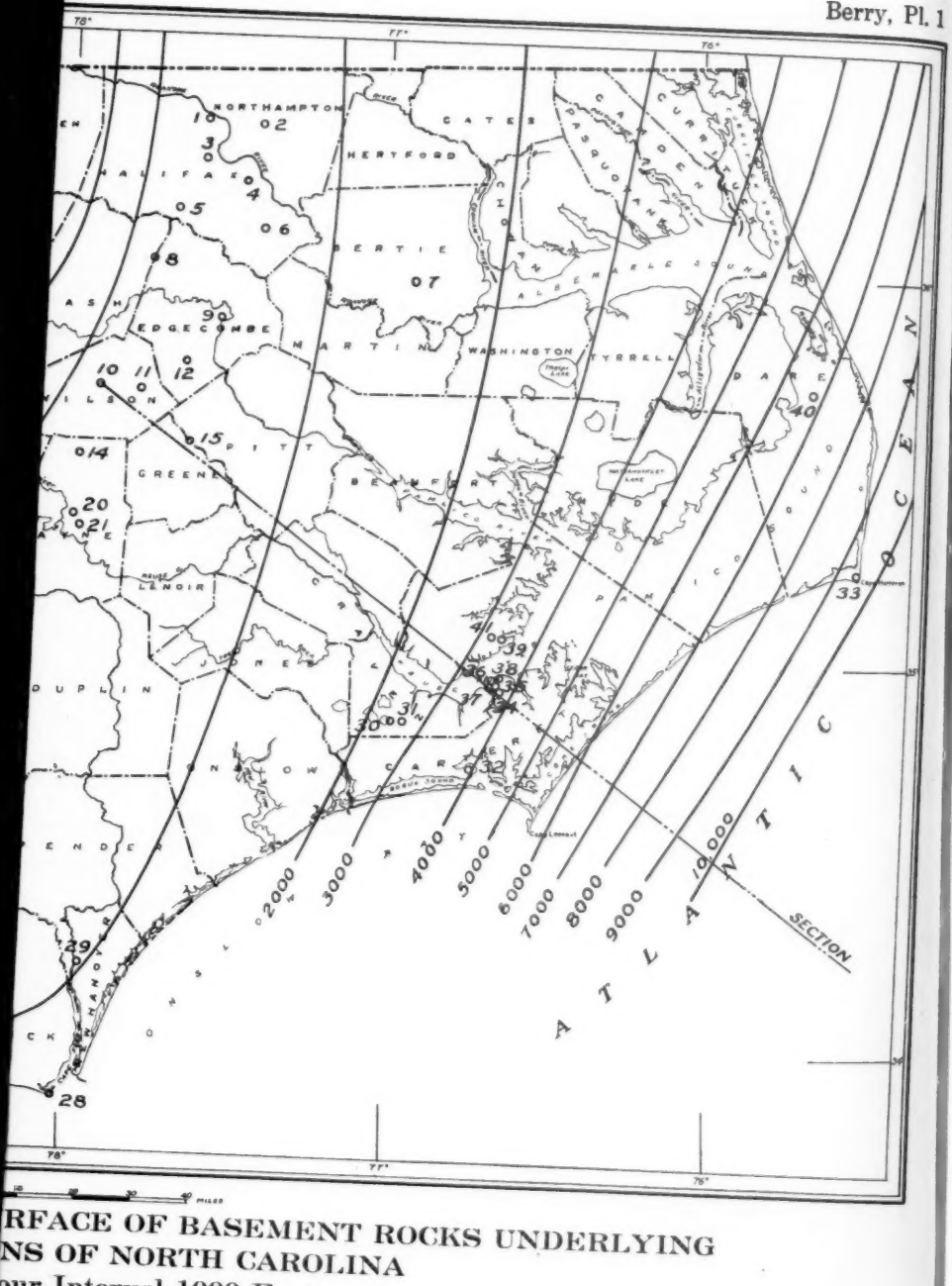

RFACE OF BASEMENT ROCKS UNDERLYING
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BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 59, PP. 87-90, 1 FIG., 1 PL. FEBRUARY 1948

NORTH CAROLINA COASTAL PLAIN FLOOR

BY WILLARD BERRY

ABSTRACT

On the basis of recent drilling, the author has reversed and brought up to date the basement slopes of the North Carolina Coastal Plain Floor. There are shown to be two gradients, a gentle slope of 10 to 14 feet per mile and nearer the coast a steeqer slope of 122-124 feet per mile.

The first contour map on the basement rocks under the Coastal Plain that is known to the writer was published in 1912 by the State of North Carolina (Clark, 1912). This showed an even sloping basement with 500-foot contour interval and is based on 55 wells penetrating the basement and 22 holes listed on the map. The next addition to the list is the hole near Havelock which was drilled in 1924–1925 and reached granite at 2318 feet (–2288) (Mansfield, 1927).

In 1944 Mundorf listed five additional holes to basement. The next addition was in 1945; F. L. Karston drilled the Laughton No. 1, 3 miles northwest of Moorehead City, and 4 miles south of Harlowe on the south bank of Newport River, Carteret Co. This hole penetrated granite at 4030 feet (–4013) with a total depth of 4044 feet. The Standard Oil of New Jersey abandoned its Hatteras Light No. 1 near Buxton, Dare County, in July 1946 at a total depth of 10,054 feet. The granite was cut at a depth of 9878 feet (–9860 feet). The Carolina Petroleum Company abandoned its Guy M. Carraway No. 1 at a total depth of 4069 feet in July 1946. It cut the granite at 4054 feet (–4036 feet). Nita Carraway No. 1 was abandoned at a depth of 4126 feet in August 1946 and cut the granite at 4120 feet (–4105 feet). The D. L. Phillips-State of North Carolina No. 1 was abandoned at a depth of 3964 feet in September 1946 and cut the granite at 3946 feet (–3933 feet). The H. B. Salters No. 1 was abandoned at a depth of 3963 feet in October 1946 and cut the granite at 3955 feet (–3941 feet). The John Wallace No. 1 was abandoned at a depth of 4024 feet in December 1946 and cut the granite at 4020 feet (–4010 feet). These five holes are near Merrymans (Merrimon), Carteret County. The Carolina Petroleum then moved into the Havelock area and drilled the Charles Bryan No. 1 about 1½ miles east of the Ellis Lake Hole drilled in 1924. This hole was abandoned at a depth of 2435 feet in January 1947 and cut the granite at 2408 feet (–2361 feet). This hole was drilled to check the basement of the earlier hole, which it did. The North Carolina Pulp Wood No. 1 was abandoned February 25, 1947, at a total depth of 3667 feet and cut the granite at 3658 feet (–3647).

The Standard Oil of New Jersey abandoned North Carolina Esso No. 2 at a depth of 6410 feet in March 1947 without reaching the basement. This was the first "Water hole" in North Carolina and was located in Pamlico Sound about 10 miles south of Wanchese, Roanoke Island, Dare County. The Carolina Petroleum Com-

TABLE 1.—*Holes cutting basement and elevation of basement as regards sea level*
(Numbers refer to holes on the map)

1. Weldon	+50	22. Manchester	+50
2. Jackson	−160	23. Fayettville	−100
3. Halifax	+60	24. Hamlet	−125
4. Tillery	−130	25. Maxton Glider School	−143
5. Enfield	−9	26. Red Springs	+70
6. Scotland Neck	−255	27. Chadborun	−385
7. Windor	−500	28. Ft. Caswell	−1532
8. Battleboro	−8	29. Wilmington	−1100
9. Tarboro	−275	30. Havelock, Great Lakes Drilling Co.	−2268
10. Wilson	+90	31. Havelock, Charles Bryan No. 1	−2361
11. Wilson—9 mi east	−112	32. Karston, Laughton No. 1	−4013
12. Pinetops	−242	33. Hatteras Light No. 1 N. C. Esso 1	−9960
13. Kenly	+180	34. Guy Carraway No. 1	
14. Freemont	+40	35. Nita Carraway No. 1	
15. Farmville	−385	36. Philips No. 1	−4000
16. Smithfield	+120′	37. Salter No. 1	
17. Selma	+150′	38. Wallace No. 1	
18. Pinelevel	+120′	39. N. C. Pulp No. 1	−3647
19. Dunn	+120′	40. N. C. Esso No. 2—abandoned 6410	(−7200?)
20. Goldsboro	−65	41. Atlas Plywood No. 1	−3406
21. Seymore Johnson Field	−120		

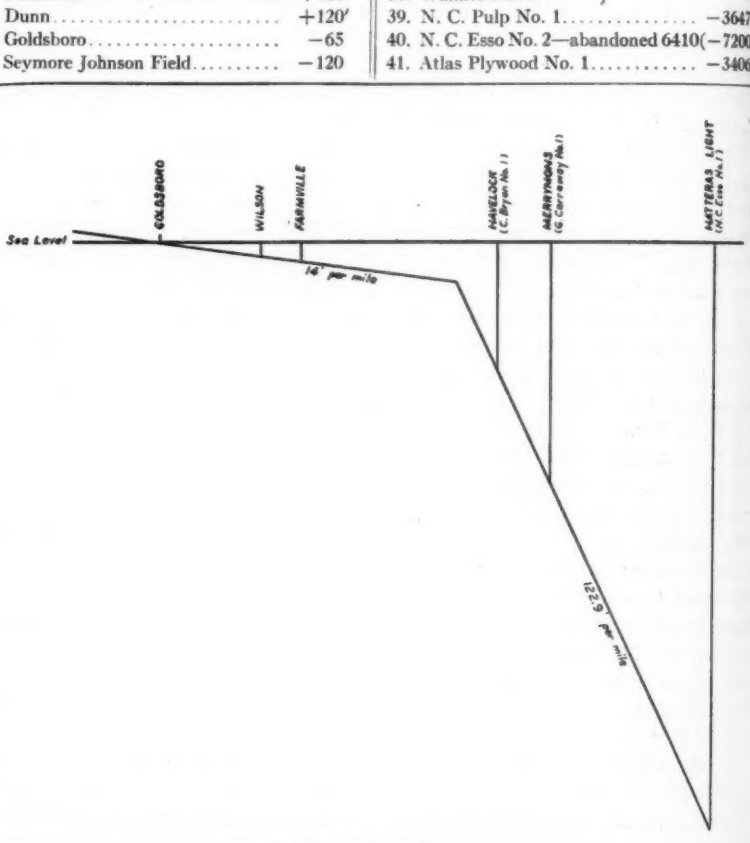

FIGURE 1.—*Generalized cross section*

Along A–A′, showing two gradients of the basement surface. Grade of gentle slope—10 to 14 feet per mile; grade of steeper slope, 122-124 feet per mile. Data are from the following drill holes: 9 miles east of Wilson, Wilson County; Farmville, Edgecomb County; 6 miles west of Havelock, Craven County; Merrymans (Merrimons), Carteret County; and Buxton, Dare County.

pany abandoned Atlas Plywood No. 1 when it reached granite at 3414 (−3406 feet) T.D. 3425 feet, this hole is about 8 miles west of Pamlico, Pamlico County.

This gives us some 69 points on the basement rocks. When plotted these points show quite conclusively that we have two different gradients to the basement rocks of the Coastal Plain. This double gradient is not shown by Richards (1945, p. 952) as the more easterly holes had not yet been drilled. Prouty reports this double gradient in his paper (1946) and shows it in a generalized cross section through Durham, Raleigh, Goldsboro, Havelock Well, Laughton No. 1, and Hatteras Light No. 1, and on his map of the area. Since his paper was written (Aug. 6, 1946) seven additional holes have been drilled. These all confirm Prouty's ideas.

The generalized cross section (Fig. 1) with the wells projected is on a line drawn from wilson to Merrymans (Merrimon). This section has five points along it and shows the two slopes. The contour map shows these two slopes using a 1000-foot contour interval.

The more gently sloping surface is probably the Schooley peneplain as stated by Prouty, but whether the steeper plain is the Fall Zone peneplain or not is a question I am not prepared to say. The gently sloping surface has a gradient of 14 feet per mile, and the steeper surface 122 feet per mile (exactly 122.9 in most cases), confirming the figures of Prouty.

I am in agreement with Prouty that we have here two definite peneplains. Attention is called to the possibilities of faulting or folding, either of which could cause the same changes of grade. There is no evidence to prove or disprove any of these conjectures.

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Duke University, Durham, North Carolina

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CORRELATION OF THE MISSISSIPPIAN FORMATIONS OF NORTH AMERICA *

BY THE MISSISSIPPIAN SUBCOMMITTEE, J. MARVIN WELLER (*Chairman*), JAMES STEELE WILLIAMS, WALTER A. BELL, CARL O. DUNBAR, LOWELL R. LAUDON, RAYMOND C. MOORE, PARIS B. STOCKDALE, P. S. WARREN, KENNETH E. CASTER, CHALMER L. COOPER, BRADFORD WILLARD, CAREY CRONEIS, CLYDE A. MALOTT, PAUL H. PRICE, AND A. H. SUTTON

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* *Editor's Note:* On the chart, the use of bibliographic reference by number makes it advisable to depart from regular Bulletin style of references in the text and end bibliography.

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INTRODUCTION

This is Number 5 of a series of correlation charts of North American sedimentary formations prepared by the Committee on Stratigraphy of the National Research Council with the co-operation of other American stratigraphers (81).

THE MISSISSIPPIAN SUBCOMMITTEE

In 1932 the Committee on Stratigraphy of the National Research Council was organized under the chairmanship of C. O. Dunbar (81). Carey Croneis, one of the original members, was designated Chairman of the Mississippian subcommittee which was organized early in 1933 and consisted of W. A. Bell, R. C. Moore, C. A. Malott, P. B. Stockdale, P. H. Price, J. M. Weller, A. H. Sutton, and P. S. Warren. Later this subcommittee was enlarged by the addition of C. L. Cooper, K. E. Caster, and Bradford Willard.

Work was started immediately on what was planned to be a volume on the *Stratigraphy of the Mississippian System in North America*, which was to include a correlation chart of the Mississippian formations. Columnar sections were prepared for various areas by the subcommittee members, and several more or less preliminary manuscripts were submitted to the chairman. It soon became apparent, however, that this project, undertaken by the subcommittee with great enthusiasm, was a much more formidable task than had been anticipated by anyone. As time passed, emphasis on the work imperceptibly shifted from an effort to complete the planned volume to an effort to complete the correlation chart alone.

After many difficulties, a preliminary correlation chart was prepared under the chairman's direction in 1938 and submitted to the subcommittee members and others for criticisms and suggestions. With the aid of these the chart was subsequently partially revised. Further work on this project, however, became more and more difficult because of increasing demands made on the chairman by his other duties. When it became apparent, in 1944, that there was little prospect of the correlation chart being completed within a reasonable length of time the chairman resigned, and J. M. Weller was appointed to take his place.

In December 1944 the new chairman reactivated the subcommittee and appointed as new members J. S. Williams, C. O. Dunbar, and L. R. Laudon. The members and their general assignments have been as follows:

W. A. Bell	Eastern Canada and Newfoundland
K. E. Caster	Northwestern Pennsylvania
C. L. Cooper	Arkansas, Oklahoma, and Texas
Carey Croneis	Arkansas, Oklahoma, and Texas
C. O. Dunbar	Arctic islands and New England
L. R. Laudon	Iowa, Oklahoma, and New Mexico
C. A. Malott	Indiana
R. C. Moore	Western States
P. H. Price	West Virginia
P. B. Stockdale	Indiana, Ohio, and Eastern Kentucky
A. H. Sutton	Illinois, Western Kentucky, and Southeastern States
P. S. Warren	Western Canada
J. M. Weller	Illinois, Western Kentucky, and Southeastern States
Bradford Willard	Pennsylvania
J. S. Williams	Alaska and Western States

With the aid of new material submitted by some of the subcommittee members, the chairman prepared, early in 1945, a new and much expanded preliminary correlation chart in 11 parts. As soon as completed each part was transmitted for criticisms, corrections, and suggestions to the complete membership of the subcommittee, to all State geological surveys in the respective areas, and to numerous individual geologists interested in those regions. The completed correlation chart, presented herewith, is the result of two revisions of the preliminary chart made in the light of information received from all these sources.

Persons other than subcommittee members who have aided in this project are as follows: A. L. Anderson, A. R. V. Arellano, C. A. Arnold, G. H. Ashley, C. L. Baker, E. M. Baldwin, N. W. Bass, R. L. Bates, Arthur Bevan, M. P. Billings, D. L. Blackstone, A. J. Blair, K. E. Born, W. B. Boyd, A. E. Brainerd, C. C. Branson, E. B. Branson, R. A. Brant, H. B. Burwell, Charles Butts, Guy Campbell, G. H. Chadwick, T. G. Chapman, E. L. Clark, P. E. Cloud, Jr., W. A. Cobban, G. V. Cohee, B. N. Cooper, G. A. Cooper, H. E. Culver, L. W. Currier, C. F. Deiss, B. J. Doherty, R. H. Dott, Allen Ehlers, G. M. Ehlers, Ralph Esarey, J. C. Frye, Winifred Goldring, Mackenzie Gordon, Jr., John Grohskopf, F. F. Grout, Herman Gunter, H. G. Hershey, J. Huner, Jr., E. C. Jacobs, O. P. Jenkins, J. H. Johnson, M. E. Johnson, D. J. Jones, P. B. King, R. E. King, Edwin Kirk, W. M. Laird, Wallace Lee, R. P. Lehman, Max Littlefield, S. J. Lloyd, J. T. Lonsdale, J. D. Love, Helen M. Martin, C. W. Merriam, T. R. Meyers, A. K. Miller, F. H. Moffit, C. A. Moore, W. L. Moreman, W. C. Morse, E. R. Nelson, Jr., T. B. Nolan, E. L. Packard, C. F. Park, J. F. Pepper, E. S. Perry, Garland Peyton, F. B. Plummer, W. F. Pond, R. S. Poor, E. C. Reed, J. C. Reed, D. B. Reger, J. T. Richards, Gordon Rittenhouse, J. C. Roehm, C. P. Ross, E. P. Rothrock, J. T. Rouse, H. W. Scott, E. H. Sellards, R. E. Sherrill, J. T. Singewald, Jr., L. L. Sloss, R. A. Smith, Wilber Stout, Alexander Stoyanow, J. L. Stuckey, D. H. Swann, C. K. Swartz, Steven Taber, N. L. Taliaferro, Thomas Thayer, H. D. Thomas, F. E. Tippie, Lyman Toulmin, Jr., J. M. Trefethen, A. C. Trowbridge, E.

L. Troxell, R. C. Tucker, W. R. Wagner, C. E. Weaver, F. G. Wells, Harry Wheeler, L. E. Workman.

Responsibility for the organization of the final chart in most of its details is as follows:

Alaska	J. S. Williams
Western Canada	P. S. Warren
Mexico	J. M. Weller
Western United States	J. S. Williams with the aid of R. C. Moore
Central and Eastern United States	J. M. Weller with the aid of other subcommittee members
New England and Arctic Islands	C. O. Dunbar
Eastern Canada and Newfoundland	W. A. Bell

Various decisions regarding the form and style of the chart, the selection of representative columns, details of correlation, and the scope and organization of the accompanying text have been made by the chairman with the advice of the other subcommittee members. He also is largely responsible for the accompanying text which is based in part on notes submitted by some of the other subcommittee members. The text has been read and criticized at various stages by the subcommittee members and others.

With the completion of this correlation chart the Mississippian subcommittee was disbanded.

OBJECTIVES

An attempt has been made to include in the chart all Mississippian formation names in current use and more or less good standing. More than 400 stratigraphic names are shown including a few that have been used in different regions with different meanings. Most stratigraphic names that have failed to obtain recognition or that have been abandoned or are otherwise no longer useful, some names of very limited application, and a number of member names have been omitted although some of these are mentioned in the accompanying text. Some less desirable names or well known names that have been supplanted by others are shown in parentheses. A few names of questionable application or names tentatively applied are enclosed between quotation marks. Information regarding most of these names can be obtained from Wilmarth's *Lexicon* (319) and its contained references.

The results of this policy are not entirely satisfactory, and in some instances they are not consistent. The extremely variable quality of the information and evidence available to the Mississippian subcommittee has made this practically unavoidable. For example, some areas, insofar as known, have not been critically re-examined for 50 years or more whereas recent, important, and unpublished information on others is at hand. Also many published lists of fossils were recorded before the faunal succession of the type Mississippian region was well understood, and they are hopelessly out of date. Often, conclusions were drawn by persons unfamiliar with the faunal succession and stratigraphy of the type region. Many of these collections are now unavailable, and few could be re-examined especially for this project. On the other hand, recent information on several undescribed and unrecorded faunas has been made available to the subcommittee.

As new data on the stratigraphy and paleontology of the Mississippian System will continue to be discovered and made known for many years to come, it is obvious that any correlation chart presented at this time can be regarded only as a report of progress. Moreover, few correlations can be accepted as final because any correlation is more or less subjective and based upon incomplete evidence which is generally incompletely understood. It may be possible to establish with certainty that strata in widely separated areas are physically continuous by tracing them in outcrops and closely spaced well records. However, this does not establish a reliable correlation because correlation involves the fitting of strata into an accurate time frame, and it is a well known fact that physical environments and resulting lithologic peculiarities and even faunal assemblages shifted and migrated across time boundaries. Some of the knottiest problems in stratigraphy occur in areas where such shifting is known to have occurred. Doubtless less conspicuous and as yet unsuspected similar shifting took place elsewhere.

In general, the Mississippian subcommittee has accepted as its objective only the correlation of various recognized stratigraphic successions as appears most probable in the light of available evidence. In most States that have active and progressive geological surveys the successions of formations shown on the chart have been furnished by these organizations. In other States stratigraphic sections have been taken from the most recent official publications of the United States Geological Survey (particularly in the West) or other more recent and apparently authoritative publications. The quality of data from this last source is quite variable, and the systems of stratigraphic nomenclature employed lack some of the consistency achieved in most official State and Federal reports. With very few exceptions, however, the formations shown on the chart are those actually recognized locally in the areas represented by the various columns, and the efforts of this subcommittee have been directed almost solely to the placement of these formations in a unified time frame and their correlation one with another. In a few regions, however, stratigraphic sections have been revised in the light of recently acquired information.

An examination of the chart will show many apparent inconsistencies in the use of stratigraphic names. The subcommittee, however, does not consider that its duties include recommendations as to what any stratigraphic unit should be termed at any place. The satisfactory solution of such problems in stratigraphic nomenclature involves many difficulties and will require the co-operation, best thought, and final compromise of numerous geologists and geological organizations.

PLAN OF CHART

The Mississippian correlation chart is presented in conventional columnar form. It is based upon no scale indicative of elapsed time or thickness of strata. The vertical space assigned to each formation is dependent mainly upon the space required to represent formations of supposedly similar age in other columns. The absence of strata is shown by vertical ruling, but no attempt has been made to indicate local or relatively unimportant unconformities and the consequent absence of insignificant parts of the stratigraphic section.

Strata of the Mississippian System are among the most widespread in outcrop and

among the most intensively studied rocks in North America. Consequently an unusually large number of columns is required to show the relationships of the many described stratigraphic sections. Columns representing the formations of this system have been carefully selected in an attempt to show as fully as possible all variations in the stratigraphic section and the nomenclature recently applied to it. Some generalization, however, has been necessary to hold the chart within reasonable limits.

Obviously it is impossible to arrange the columns so that each is closely adjacent to all others with which it is related or to which it should be compared. The plan of arrangement is as follows:

Starting in Alaska the columns extend southeastward along the Pacific coast and are followed by sections at various places in the Great Basin, Colorado plateaus, and neighboring regions arranged somewhat irregularly. Returning to the north, columns for various parts of the Rocky Mountains (also the Black Hills) follow each other in a southeastern direction. Next come columns for the Southwest Interior region of Texas, Oklahoma, and Arkansas. These are followed by columns illustrating several subsurface sections in the Mid-Continent region. Columns for outcropping sections are resumed in the southern Ozarks and extend from west to east. Next comes the central part of the chart devoted to the type area with columns starting in central Missouri, jumping to north-central Iowa, and continuing around the border of the Eastern Interior basin by way of the Mississippi River, through western Kentucky, and into Indiana. These are continued by columns for subsurface sections of the Eastern Interior basin. Sections present in the Northern Interior or Michigan basin follow. These are continued by columns at intervals along the band of Mississippian outcrops east of the Cincinnati arch from northern Ohio to Mississippi. Next comes the Appalachian region with columns extending from Alabama to Pennsylvania along the eastern side of the Allegheny and Cumberland plateaus and their southern extensions. After these are columns illustrating subsurface sections in the northern part of the Appalachian basin. Jumps are now made to New England and to the Maritime Provinces of Canada and Newfoundland, and the chart is concluded with columns for the Arctic islands. Altogether, columns are presented for 33 of the United States, New England, Alaska, four provinces and two territories of Canada, Newfoundland, two States of Mexico and Greenland.

At the-left hand margin of the chart are columns showing the standard classification and the standard stratigraphic section of the type area in the upper Mississippi valley against which all columns are correlated. It is not known that this classification is applicable to all of North America, but no general classification of more than local application has been proposed for any of the outlying regions. These columns are accompanied by others showing the known ranges of various useful guide fossils. The first of these shows the ranges of genera or species important in the type area. Some of these are also useful in the more eastern States, but the significance of their presence or absence in most other regions is little known. Other columns show the known or presumed ranges of certain ammonoids and plants believed to be of broad regional significance. They are much generalized.

At the right hand margin of the chart the European classification is presented and tentatively correlated with the standard American classification.

Numbers at the foot of each column of the chart refer to the appended bibliography. Most of the publications so indicated are not the original articles in which the respective stratigraphic sections were described but refer to later descriptions and discussions from which references to the older literature can be obtained. Text references are given similarly. Some refer to several pages but only the first is indicated.

CLASSIFICATION OF MISSISSIPPIAN ROCKS

The Mississippian rocks of North America are approximately equivalent to the Lower Carboniferous rocks of Europe and have been variously treated as a series or "subsystem" of the Carboniferous System or as an independent system. Although the name Mississippian has been used for a subdivision of the Carboniferous since 1869 (321, p. 79), the Mississippian Period was first formally recognized by Chamberlin and Salisbury in 1906 (49, p. 496). Since about 1915 the Mississippian Period has been widely accepted in the United States (50, p. 128). The Mississippian subcommittee, in acknowledgment of this situation, considers that the Mississippian rocks constitute a system separate from and comparable to the Devonian and Pennsylvanian systems which enclose it.

SUBDIVISION OF MISSISSIPPIAN IN TYPE AREA

Primary subdivision.—The major features of the type Mississippian section were worked out nearly 100 years ago in Iowa and Illinois by Hall and Worthen, and the formations described by the former are still recognized in this region (101, p. 46). In those days the terms formation and group were used more or less interchangeably, and the groups proposed by the early writers did not possess the significance that groups now have for stratigraphers. Worthen, however, was the first geologist in this region to combine several Mississippian formations to form a group (327, p. 77). His classification of 1866 exerted a strong influence on all that followed and demonstrates clearly that the four principal divisions of the Mississippian System now recognized have come down from his time with little change (Fig. 1).

The relative importance of the Chesterian or Upper Mississippian was not appreciated before Ulrich's work in western Kentucky (269), and probably for that reason several of the classifications before 1900 combined the present Chesterian and Meramecian series into a single group (238, p. 292; 292). A similar subdivision of the Mississippian System into upper and lower parts was later emphasized by Ulrich (269, p. 24) although H. S. Williams previously had clearly expressed his view that the fossils showed such a separation to be primarily important (314, p. 169).

Stuart Weller's extensive studies of the Chesterian led him to propose a different two-fold division (299, p. 282; 300, p. 91). His Iowa Series has received little recognition outside of Illinois, although his classification strongly influenced most subsequent stratigraphic studies in the Central States.

Moore, J. M. Weller and Sutton (184, p. 261), and also E. B. Branson (20, p. 5) have recognized somewhat similar three-fold classifications of the Mississippian, and a recent poll indicates that this is the view held by most American geologists (50, p. 135). Moore also has presented a different three-fold classification (187, p. 671)

Standard Section	Northen 1864	Sharon 1873	Broadhead 1874	Williams 1891	Keyes 1892	Keyes 1893	Weller 1898	Ulrich 1905	Weller 1907	Ulrich 1911	Weller 1914	Weller 1920	Cumings 1922	Moore 1928	Moore 1933	Moore 1937	Bronson 1938–44	Weller & Sutton 1940	This Chart
Kinkaid ls.	Chester group																		
Degonia ss.																			
Clore fm.																			
Palestine ss.																			
Menard ls.																			
Waltersburg ss.																			
Vienna ls.																			
Tar Springs ss.																			
Glen Dean ls.																			
Hardinsburg ss.																			
Golconda fm.																			
Cypress ss.																			
Paint Creek fm.																			
Bethel ss.																			
Renault ls.																			
Aux Vases ss.																			
Ste. Genevieve ls.																			
St. Louis ls.	St. Louis group					St. Louis group													
Salem ls.																			
Warsaw ls.																			
Keokuk ls.	Keokuk ss. Borden ss.																		
Burlington ls.		Archimedes group	St. Louis group	Genevieve group	Kaskaskia group	Augusta group	Ste. Genevieve group	Chester group	Meramec group	Meramec group	Meramec group	Meramec group	Meramec group	Meramec group	Meramec group	Meramec group	Middle Mississippian	Meramec group	Meramecian series
Fern Glen fm.																			
Gilmore City ls.	Escrinital ls.																		
Sedalia ls.	Chamung																		
Chouteau ls.	Kinderhook group	Chouteau group	Kaskaskia group	Chouteau group	Kinderhook group	Kinderhook group	Kinderhook group	Osage group	Osage group	Osage group	Osage group	Osage group	Osage group	Osage group	Osage group	Osage group	Lower Mississippian	Osage group	Osagean series
Hannibal sh.																			
Louisiana ls.																			
Saverton sh.																			
Grassy Creek sh.																			
References	327	238	24	314	128	129	292	269	295	270	298	300	69	183	184	187	20, 22	289	

FIGURE 1.—*Development of classification of Mississippian rocks in type area*

compromising the systems of Ulrich and Stuart Weller, which resulted from his conclusions regarding intercontinental correlations.

At present several stratigraphers, led by Laudon and Moore, have returned to Ulrich's two-fold classification, but their position has not yet been explained in print.

For the purposes of the present chart four divisions of approximately co-ordinate rank, which are recognized by practically all stratigraphers in the type area, are distinguished. They are here termed series because two of them are subdivided into subordinate groups. The possible combination of these series into two or three primary divisions is left for future investigation.

Chesterian-Meramecian boundary.—Although a four-fold subdivision of the Mississippian System has been generally accepted in the type area for many years, differences of opinion have existed regarding the boundaries between the recognized groups or series. Most field geologists and paleontologists have agreed that the Ste. Genevieve limestone is the uppermost formation of the Meramecian Series, and before 1905 strata of this age were generally referred to the St. Louis limestone. The peculiar stratigraphic situation in western Kentucky and a misunderstanding of the mutual relations of certain faunas led Ulrich to refer the Ste. Genevieve to the Chesterian. Subsequent uncertainty regarding the affinities of the Ste. Genevieve caused it to be excluded from both the Chesterian and Meramecian in some classifications (183, p. 13; 298, p. 12), but Stuart Weller's clarification of this problem (300, p. 129) has resulted in practically unanimous agreement that this formation is properly referable to the Meramecian.

Meramecian-Osagean boundary.—Disagreement regarding the boundary between the Meramecian and Osagean series has been much more widespread and prolonged and has been concerned principally with the proper placement of the Warsaw formation. Ulrich stated that the base of the Warsaw is "an important diastrophic boundary . . . clearly indicated faunally" (270, p. 588). Laudon believes that the "greatest stratigraphic break in the whole Mississippian occurs at the top of the Keokuk and that the fauna of the overlying Warsaw is almost entirely strange to the Osage." In contrast to these opinions Stuart Weller wrote "Lithologically there is no satisfactory basis for differentiating the Warsaw from the subjacent Keokuk, and the faunal relations of the two formations are very close" (298, p. 19). Similarly, Moore formerly believed that "The Warsaw . . . rest(s) conformably on the Keokuk" and its "fauna . . . is very similar to that of the Keokuk" (185, p. 243), but he now holds a different view. J. M. Weller expressed the opinion that no consistent upper boundary of the Warsaw can be recognized in the Mississippi Valley (286, p. 106), and Weller and Sutton pointed out that the regional lithologic variations of the Warsaw are similar to overlying rather than underlying beds and, therefore, they considered it to be part of the Meramecian (298, p. 811).

Current usage is not consistent. The United States Geological Survey classes the Warsaw formation in the Meramecian, and this practice is followed by the Missouri Geological Survey. The state geological surveys of Indiana, Iowa and Illinois, however, classify the Warsaw with the Osagean although Stuart Weller, in his last important Illinois publication, referred it to the Meramecian (300, p. 96).

Laudon suggests that this confusion and disagreement has been caused by failure

to recognize the proper boundary between the Keokuk and Warsaw formations in the type area and that the inclusion of upper Keokuk shaly beds with strata of similar lithologic characteristics in the Warsaw has resulted in the mixing of essentially distinctive faunas. A careful restudy of the area to test this possibliity should be undertaken.

Although no unconformity has been demonstrated in the type area, a pronounced physical break at this position is believed by some to occur in the Mid-Continent region where Lee reports that the Cowley formation completely overlaps all older Mississippian strata and locally also upper beds of the Ordovician dolomite (151, p. 94). Laudon states that the Moorefield can be seen in outcrop in contact with every bed from the top of the Keokuk limestone to the Chattanooga shale in a distance of a few miles in the Cookson Hills area of Oklahoma. Also Laudon reports the occurrence of a striking unconformity in New Mexico where, along the Sacramento Mountain front, the basal Helms cuts out and overlaps a complete Caballero-Lake Valley succession in less than 15 miles.

Possibly part of this disagreement has been caused by miscorrelation of beds, particularly in southwestern Missouri and Indiana, with the principal part of the type Warsaw rather than with the upper part of the Keokuk. Thus Moore now believes that the so-called Warsaw of southwestern Missouri is upper Keokuk, and Stockdale considers the Lower Harrodsburg (part of the so-called Warsaw) of Indiana to be equivalent to beds of Keokuk age in Kentucky.

This problem is particularly important because of the growing belief that a primary separation of the Mississippian System into Upper and Lower parts should be made between the Meramecian and the Osagean. New ideas and better understanding of stratigraphic and faunal relations are causing some of the opposition to the placement of the Warsaw formation in the Meramecian Series to disappear. Because of this, and because fewer difficulties are encountered in the correlation and classification of other apparently equivalent formations, the Meramecian-Osagean boundary is located below the Warsaw formation in the Mississippian chart.

Osagean-Kinderhookian boundary.—Uncertainty regarding the Osagean-Kinderhookian boundary necessitates the consideration of three formations. Strata later distinguished as the Fern Glen were described by Worthen who referred them to the Kinderhookian (327, p. 112). This classification was followed by all later workers until Ulrich, in 1911, transferred these beds to the Osagean (270, Pl. 29) and Stuart Weller subsequently reached a similar conclusion (302, p. 155). At present almost all geologists, except E. B. Branson, consider the Fern Glen formation to be basal Osagean.

The Sedalia limestone, long considered the upper member of the Chouteau, was correlated by both Moore and Branson with the Fern Glen (20, p. 5; 22, p. 184; 183, p. 150). Both formations were assigned to the Osagean by Moore who has been followed by others, but Branson refers them to the Kinderhookian. More recent work suggests that the correlation of Sedalia and Fern Glen is erroneous.

The Chouteau has always been recognized as a part of the Kinderhookian, and until the Sedalia was separated from it these strata also were considered Kinderhookian. Apparently Moore was influenced, in transferring the Sedalia to the Osa-

gean, by the stratigraphic and faunal associations of its supposed equivalent, the Fern Glen. In contrast, Branson seems to be influenced, in his assignment of the Fern Glen to the Kinderhookian, by the stratigraphic and faunal relations of its supposed equivalent, the Chouteau. Although all do not agree, the present consensus is that Sedalia is Kinderhookian and Fern Glen is Osagean. This problem is not settled, however, and further study is needed before unanimity of opinion can be achieved.

The Gilmore City limestone (also termed Alden) has not been included previously in the standard Mississippian section. This formation outcrops in an area in Iowa where its relations to other Mississippian formations are not clear, and it has been referred tentatively to the Kinderhookian, Osagean, or Meramecian. Subsurface studies, extending as far as southwestern Kansas, have shown the widespread existence of similar oölitic limestone which occupies a stratigraphic position between beds of Sedalia and lower Osagean lithology (151, p. 41). Thus placed, this formation is referred to the Kinderhookian Series because its fauna, and particularly its crinoids as determined by Laudon, show unmistakable Kinderhookian affinities (144, p. 33).

The Fern Glen and Gilmore City formations crop out only locally, and they were not known or considered by most writers who sought to set up a general Mississippian classification. Consequently, in the accompanying chart showing the development of Mississippian classification, these formations are not included in the named groups of some columns. Other authors, however, by including the Fern Glen in the Kinderhookian or the Sedalia in the Osagean, have automatically but unknowingly carried the Gilmore City into the same group.

Groups.—The subdivision of the Chesterian Series into three groups has been recognized for more than 25 years. Mostly these have been termed Lower, Middle, and Upper Chester. Geographic names proposed by Weller and Sutton (289, p. 766) are indicated on the chart although they have been little used up to this time.

Two new Kinderhookian groups are introduced on the Mississippian chart. The Easley group includes all Kinderhookian strata which are almost universally recognized to be of Mississippian age. The name is derived from a station on the Missouri, Kansas and Texas Railroad in Boone County, Missouri. The Fabius group consists of those Kinderhookian strata which are believed by some to be Mississippian but by others to be Devonian (20, p. 5). This name is taken from South Fabius River which flows from Knox through northern Marion County, Missouri. Both names have been approved as suitable by the Missouri Geological Survey, although E. L. Clark states that this organization prefers the designations Upper and Lower Kinderhookian.

SUBDIVISIONS IN OTHER REGIONS

The classification adopted for the Mississippian correlation chart is not known to be applicable throughout North America. Both east and west of the type area a rough two-fold subdivision has generally been recognized. To the east these parts are separated approximately at the boundary between the Chesterian and Meramecian series and correspond to the Pocono and Mauch Chunk of Pennsylvania as these formations are generally understood. To the west, division is largely based

on faunal evidence, and the separation appears to correspond approximately to the Meramecian-Osagean boundary.

The Kinderhookian affinities of certain western faunas have been recognized for many years, and the Kinderhookian Series is believed to be well represented in that region (91, p. 217), but no boundary has been determined to separate Kinderhookian from Osagean strata throughout its greater part.

To the east, Kinderhookian beds generally have not been recognized, and some believe that this series is unrepresented in large areas. Possibly, however, strata of this age are included in the Osagean because fossils are rare or have been inadequately studied.

The approximate boundary between the Meramecian and Osagean series can be determined on the basis of fossil evidence at most places in the United States east of the type area, but physical evidence indicative of an important break at this horizon in this region has not been recorded.

Separation of the Chesterian and Meramecian series in the west is very uncertain. Fossils characteristic of each series have been reported from widely separated localities, but some important faunal associations appear to be different from those in the type area, and stratigraphic ranges of most forms have not been determined adequately.

No classification of more than local application has been proposed for either the eastern or western region. Careful paleontologic studies are urgently needed in both of these regions before many of the recognized Mississippian formations can be satisfactorily correlated and classified.

LOWER BOUNDARY OF MISSISSIPPIAN SYSTEM

Black shales of questionable age separate undoubted Devonian and Mississippian rocks throughout much of the interior of North America. They extend almost continuously from Michigan on the north to Alabama on the south, and from Virginia on the east to Alberta and New Mexico on the west. Numerous names have been applied to these beds, and various ages have been assigned to them. Originally most of the black shales were classed with the Devonian, but, since Ulrich stated his contention that the Chattanooga shale is Mississippian (271), his view has been adopted by numerous others.

In parts of Arkansas, Oklahoma, and Texas, strata that occur at the position of, and apparently are equivalent in age to, black shale in near-by areas are composed largely of novaculitic chert. Fossils in both the black shale and chert are comparatively scarce and very restricted in variety so that conclusions based on paleontology are none too certain. C. L. Cooper summarizes the evidence at present available as follows:

"Three different conodont zones were recognized by Huddle in the New Albany shale of Indiana (114, p. 11). The lowest zone yielded a fauna similar to assemblages known from the Upper Devonian of New York (Genundewa and Rhinestreet). These or closely related beds at various places also contain *Lingulipora*, *Styliolina*, *Hypothyridina*, *Schizobolus*, *Leiorhynchus quadricostatum*, *Tornoceras*, and *Spathiocaris cushingi*. These beds are quite generally conceded to be Upper Devonian and have been correlated with the Geneseo and Tully of New York (62, p. 1736).

"The middle New Albany zone contains conodonts similar to those known in the Chattanooga shale near Huntsville, Alabama, the 'Kenwood' shale of southeastern Wisconsin, the Grassy Creek shale of the upper Mississippi valley, the lower part of the Woodford chert of Oklahoma, and the typical Exshaw shale of Alberta. *Callixylon* also occurs in the middle part of the New Albany and has been found in the Antrim of Michigan and the Huron and lower Ohio shales of Ohio.

"Near the top of the upper New Albany is a thin, possibly local, gray shale (Underwood) which contains a small brachiopod fauna suggesting a correlation with the Hamburg and Glen Park limestones of the Mississippi Valley and the Bedford shale of Ohio and eastern Kentucky. Some of the ostracodes from this zone also occur below the Darty limestone of southern Illinois, the Louisiana limestone of western Illinois and eastern Missouri and in the pre-Welden shale of Oklahoma. A gray shale (Olinger) in the midst of the black Chattanooga shale of Tennessee contains *Lingula irvinensis*, *Rhipidomella*, *Chonetes acutiliratus*, *Schuchertella*, and rhynchonellids which suggest its correlation with the Bedford-Berea zone to the north.

"At or near the top of the New Albany is a zone of peculiar small phosphatic concretions (Falling Run) that is persistent throughout southern Indiana and has been traced southward into Kentucky and Tennessee (44, p. 848). Some of these concretions contain specimens of *Spathiocaris williamsi* and other crustaceans which are known elsewhere only in the upper third of the Woodford chert in Oklahoma and in the Cleveland shale of northern Ohio. The Woodford specimens also occur in similar concretions but these are not restricted to a single zone as they appear to be in the upper New Albany. Almost identical concretions also occur in the upper part of the Percha shale in New Mexico but their fauna, if any, is as yet unknown.

"The conodonts of the upper New Albany zone are similar to those present in the Cleveland and Sunbury shales of Ohio, the Chattanooga shale near Huntsville, Alabama, the Hannibal shale of the upper Mississippi valley, the Woodford chert of Oklahoma (59), and black shales at the base of the Mississippian in Montana and Alberta (61). These beds are now generally conceded to be Mississippian.

"The top of the New Albany is separated from the Rockford by a thin calcareous shale (Jacobs Chapel) containing a prolific conodont fauna identical to that found in the pre-Welden shale in Oklahoma (60) which has been correlated with the Bushberg-Hannibal formations of the Mississippi Valley.

"Thus it appears that the boundary between the Devonian and Mississippian systems occurs within the New Albany shale and its equivalents elsewhere. Although unconformities in the midst of the black shale have been reported (210), no breaks in this sequence are obvious at most places, and lithologic similarity of Devonian strata below and Mississippian strata above makes any division difficult. Also it is as yet uncertain whether the middle New Albany conodont zone should be referred to the Devonian or Mississippian.

"This middle zone has generally been considered Devonian in states east of the Mississippi River but its equivalent, the Grassy Creek shale, in northeastern Missouri and western Illinois has generally been regarded as the basal formation of the Mississippian Kinderhookian group or series. Branson and Mehl, however, state that the conodonts of the Grassy Creek shale are unmistakably Devonian, and because of the close stratigraphic relationships of the Grassy Creek and Saverton shales (they recognize only a single formation) and the Louisiana limestone, they place the Devonian-Mississippian boundary at the base of the Hannibal shale. They base their conclusion that the Grassy Creek fauna is Devonian principally on the occurrence of the conodont genera 1) *Polylophodonta*, 2) *Ancyrognathus*, 3) *Palmatolepis*, 4) *Apatognathus*, 5) *Nothognathella*, and 6) *Icriodus* (19, p. 181). So far as known at present, all but the first and fourth genera occur in undoubtedly Devonian strata. The first genus is known only in beds of middle New Albany age and the third and sixth are present in upper New Albany or younger strata. The second and fourth

genera possibly persist into beds younger than any of the New Albany. Thus the known ranges of these genera favor the Devonian assignment of the Grassy Creek (and therefore the middle New Albany) only slightly. Considered on the basis of the complete conodont fauna, however, a Mississippian age of the Grassy Creek shale appears more probable because 16 species range upward against only 2 which range downward. Figures for the middle New Albany fauna are almost the same with 17 species persisting into younger beds and only two carrying over from the undoubted Devonian. These figures, however, may be somewhat misleading because the undoubtedly Devonian fauna of the lower New Albany contains 6 species that persist into upper New Albany or younger beds and only 2 that are exclusively Devonian."

Conodont faunas do not prove the age of the New Albany. They are, however, of primary importance for the correlation of strata of New Albany age in widely separated areas.

Eastward beyond the range of Mississippian or Devonian black shales this problem becomes different and still more complicated. In Pennsylvania, West Virginia, Virginia, and Maryland the Mississippian-Devonian boundary has commonly been placed at the contact between the so-called Pocono and Catskill formations. These are generally distinguished on a lithologic basis where red shales below give way to gray sandstones above. Such rare fossils as have been recorded from the Catskill are recognized to be Upper Devonian species. Where red shales of Catskill type are absent the Pocono is presumed to overlie the Chemung formation which differs from it little lithologically but contains many distinctive Upper Devonian fossils. Southward in Virginia and Tennessee dark shales again appear immediately below recognized Mississippian strata. The lower part, consisting of the Cumberland Gap shale, is included in the Brallier formation by Butts (42, p. 318) and is of questionable age, probably equivalent to the middle part of the New Albany shale.

Thus, going southward from Pennsylvania, the Pocono formation of Mississippian age (for qualification *see* subsequent discussion) or its equivalent overlies successively strata that have been termed Catskill (red shale), Chemung (gray sandstone), and Brallier (dark shale). These are the same types of rock that, in southern New York and northern Pennsylvania, have been interpreted as facies equivalents of similar age. It is possible, therefore, that these different types of strata outcropping on the eastern margin of the Allegheny plateau region, although referred to different formations, may be in part of more or less equivalent age.

Published reports describe little or no physical evidence of a stratigraphic break at the base of the Pocono in this region, and the existence of a hiatus at this horizon seems to have been postulated principally on the absence of strata of certain lithologic types that were presumed to be younger than the uppermost Devonian formation locally recognized. It seems possible, therefore, that strata of middle New Albany age may be included locally in the upper parts of several thick clastic formations in the Appalachian region that have heretofore been assigned unquestionably to the Devonian. The fact that only Devonian fossils have been recorded from these formations is not convincing evidence as to the age of their upper parts at all places for the species identified have not been zoned, and it is uncertain from what parts of these formations most of them were obtained.

On the other hand, the Mississippian age of the Pocono, particularly in northeast-

ern Pennsylvania, has been questioned (48, p. 139), and it is possible that the Devonian-Mississippian boundary actually occurs, locally at least, higher instead of lower than has been generally supposed.

Whatever their equivalent in the northern Appalachian district, strata of middle New Albany age are commonly classed as "Devonian or Mississippian." Individual preferences for placing these beds on one side or the other of the systemic boundary depend upon the type of evidence considered. Most paleobotanists believe the plants are distinctively Devonian, and the same claim has been made for the conodonts, although this latter conclusion, as previously noted, appears to be questionable. In the middle Mississippi Valley region, however, black shale of middle New Albany age overlies older strata with remarkable regional unconformity (152, p. 63), and on all sides of the Ozarks it overlaps the Devonian and Silurian systems completely and directly succeeds Ordovician strata at numerous places. Throughout wide areas the black shale appears to have been deposited upon a peneplaned surface, but in Kansas erosion channels have been recognized in the subsurface at this contact (153, sheet 3). Although this unconformity becomes less conspicuous and perhaps disappears east of the Cincinnati arch, there is no other unconformity of comparable magnitude and significance in this part of the stratigraphic section that can be utilized to separate the Devonian and Mississippian systems. If diastrophism is accepted as the ultimate basis for the subdivision of geologic time, and if plants and animals are believed to have altered in response to the resulting physical changes, a good case can be made for accepting this unconformity as the systemic boundary (186, p. 609). Moreover the Kinderhookian, the basal unit of the Mississippian in its type region, includes beds of middle New Albany age, and thus a precedent of long standing is established.

Because the Devonian and Carboniferous systems were originally recognized in Europe and have their type localities there, it may appear logical to assume that the proper solution to the Devonian-Mississippian boundary problem in America demands that this boundary be drawn as nearly as possible to conform with the European Devonian-Carboniferous boundary. This might be true if a definite boundary between these systems were recognized and agreed upon in Europe. The situation there, however, is fully as unsatisfactory and confusing as it is in America, and uniformity of opinion on this matter does not appear to exist except in local areas. Under these circumstances, therefore, no valid reason exists to deter American geologists from attempting to agree upon the most suitable boundary for the separation of the Devonian and Mississippian systems based primarily upon evidence available in North America. If agreement can be reached here it might strongly influence whatever solution of this problem may eventually be reached in Europe.

UPPER BOUNDARY OF MISSISSIPPIAN SYSTEM

Throughout most of interior North America the Pennsylvanian System overlies older strata with marked unconformity. Thus in Illinois the Pennsylvanian overlaps northward from the uppermost Chesterian (Kinkaid) onto the Middle Ordovician St. Peter sandstone, separated in the southern part of that State by over 5000 feet of intervening strata (289, p. 847). At least locally this unconformable contact

possesses considerable topographic relief with Pennsylvanian-filled channels cut as much as 300 feet deep in western Kentucky (284, p. 151). Elsewhere, post-Mississippian—pre-Pennsylvanian faulting has been recognized (289, p. 851). The magnitude, importance, and extent of this unconformity is one of the principal reasons for the recognition of the Mississippian and Pennsylvanian as independent systems by most American geologists.

Recognition of the Mississippian-Pennsylvanian boundary is not clear, however, in certain geosynclinal areas where thick clastic and generally nonfossiliferous beds of more or less transitional age accumulated to great thicknesses. The outcrop area of this type that has attracted most attention is in the Ouachita Mountains of Arkansas and Oklahoma where the Stanley shale and Jackfork sandstone, with a combined maximum thickness of 15,000 or more feet, have been referred to the Mississippian by some and to the Pennsylvanian by others.

The Stanley and Jackfork formations are included in the Pennsylvanian correlation chart (189, p. 694), but the problem of their age is still debatable. The small flora collected from these beds has been reported to be unlike any other flora known in North America, and according to David White it is younger than the flora of the Wedington sandstone of the Fayetteville formation (Chesterian) in Arkansas and is older than the flora of the Bloyd shale of the Morrow group (Middle Pottsvillian or Lower Pennsylvanian) in the same State. He compared it, and considered it to be similar in age, to floras described from the Waldenburg and Ostrau series of central Europe (310). These latter beds have been classed with either the Lower or Upper Carboniferous but are currently referred to the Lower Namurian (E and possibly H zones). Correlation by goniatites indicates that the Lower Chesterian is probably of late Viséan age, and Moore has also presented paleontologic evidence that the Viséan-Namurian boundary falls within the Chesterian series (187, p. 662). Thus if White's correlation of the Stanley-Jackfork flora is correct, these strata are probably of Mississippian age. He assigned them to the Pennsylvanian apparently because he believed the Mississippian-Pennsylvanian boundary of the United States is approximately equivalent to the boundary between the Lower and Upper Carboniferous of Europe.

Any decision regarding the age of the Stanley and Jackfork formations must strongly influence the age assignment of the Springer formation (or series), over 3000 feet thick in the Arbuckle Mountain region of Oklahoma, and the Tesnus formation of similar thickness in the Marathon basin of west Texas. Both of these formations occupy stratigraphic positions similar to that of the Stanley-Jackfork, between novaculitic chert of Devonian or early Mississippian age and undoubted Lower Pennsylvanian beds. A few plants from the upper part of the Tesnus were believed by White to be early Pennsylvanian and slightly younger than the Jackfork flora (133, p. 61). No fossils have been found in the lower part of the Tesnus, however, and no direct evidence is known for dating this part of the formation. The few invertebrates collected from the Jackfork are poorly preserved, and the indentifications are not certain. Most of the recorded forms have near relatives elsewhere in both Upper Mississippian and Lower Pennsylvanian strata. Invertebrates from the Springer have been identified principally with Pennsylvanian species, and at least the upper part of the Springer is probably of Morrowan or closely similar age.

The Parkwood formation of Alabama has been considered to be transitional between the Mississippian and Pennsylvanian systems (34, p. 206). This formation consists of 2000 feet of gray shale and sandstone physically resembling overlying Pennsylvanian more than underlying Mississippian strata. Its lower part is believed to grade laterally into the Pennington and Floyd shales, and its upper boundary is placed arbitrarily at the base of the Brock coal bed. Fossils are very scarce, and the few specimens collected have been identified as species known elsewhere from both Mississippian and Pennsylvanian beds. Poor preservation probably renders their identification uncertain.

In southeastern West Virginia and the neighboring part of Virginia, the Hinton division of the Mauch Chunk appears to be approximately equivalent to the Upper Chesterian of the Mississippi Valley and the Pennington shale of the Cumberland plateau and neighboring regions. The upper Mauch Chunk, consisting of the Princeton and Bluestone divisions, succeeds the Hinton without noticeable break and is physically similar to underlying rather than overlying strata. The Mississippian age of these beds has rarely been questioned, although the paleontological evidence is inconclusive. Few invertebrates have been collected from the uppermost Mauch Chunk (220, p. 309), and the flora appears to include both Mississippian and Pennsylvanian types (309, p. 840). Among the invertebrates of the Hinton, however, are several typical Chester species. So far as is known at present, this region possesses the most complete stratigraphic succession of beds from the Mississippian into the Pennsylvanian System, and 1000 feet or more of strata of Mississippian age younger than any Chesterian of the Mississippi Valley area may be present. This occurrence strongly suggests that the Parkwood formation, which appears to be conformable on not more than 200 feet of Pennington, is largely of Mississippian age and likewise demonstrates that a considerable thickness of upper Mississippian strata younger than any present in the upper Mississippi Valley may be present elsewhere.

The relations of the Mississippian and Pennsylvanian systems are not well known in considerable parts of the western Cordilleran region. Much careful stratigraphic work must be done there before the problems that undoubtedly exist are adequately recognized and satisfactory solutions can be sought.

CORRELATION WITH EUROPE

The classification of formations of Carboniferous age differs on the two sides of the Atlantic; in Europe a single system is recognized, whereas in North America generally there are two systems, the Mississippian and Pennsylvanian. For many years it has been assumed that these American divisions are approximately equivalent to the European Lower and Upper Carboniferous respectively, and it is only comparatively recently that the ammonoid zones recognized in Europe have been correlated with the occurrence of similar forms in the United States. Moore has summarized this and other paleontologic evidence as follows (187, p. 660):

"Although almost all of the specific identifications of North American early Lower Carboniferous fossils differ from European identifications, similarities actually far outweigh dissimilarities. The *Spirifer tornacensis* fauna of European Tournaisian beds is almost identical in all essential features with that of the American Kinderhook and Osage beds. Typical *S. tornacensis* is apparently represented by the American *S. marionensis, S. louisianensis* and some other forms, possibly even including

such shells as *S. grimesi* and *S. logani* which are characteristic of the Burlington and Keokuk limestones, respectively, of the Osage group. Among chonetid brachiopods, the small wide ribbed *Chonetes logani* and *C. glenparkensis*, with fine concentric striations, and the large flattish fine-ribbed forms, such as *C. mulicosta* and *C. illinoisensis*, which occur commonly in the American Lower Mississippian (Kinderhook and Osage) are precisely matched by shells that are associated together in the Tournaisian. Similar close resemblances may be noted among the productids. The Osage beds and to a lesser extent the upper Kinderhook are characterized by a remarkable profusion of camerate crinoids which die out suddenly at the top of the Osage. It is significant that many of these genera occur commonly in the Tournaisian limestones of Belgium and England, although as yet identical species have not been recorded. The ammonoids, *Aganides rotatorius* and species of *Protocanites*, *Muensteroceras*, and *Pericyclus*, occur in both the American and European early Carboniferous deposits . . .

". . .excepting *Lithostrotion*, the characteristic elements of typical Viséan faunas such as *Chonetes papilionaceous*, *Daviesella*, *Productus giganteus* and a large variety of corals, are unknown in North America except for record of *P. giganteus* in the western United States . . .

"The Viséan extends upward to the base of the Namurian which is defined to begin the European Upper Carboniferous. In terms of goniatite-bearing beds, the upper boundary of the Viséan is commonly drawn at the base of the *Eumorphoceras* (E) zone and it thus includes the zones of *Beyrichoceras* (B_1B_2) and *Goniatites* (P_1P_2). *Beyrichoceras* is not known in North America but the occurrence of typical *Goniatites crenistria*, *G. newsomi*, *G. suborbicularis*, and *Sagittoceras meslerianum*, which occur both in this zone of the Upper Mississippian Chester beds in North America and in the P zone of western Europe, seems fairly definitely to indicate the upper Vesćan age of a part of the Chester. The Chester beds also include *Eumorphoceras bisulcatum* which is characteristic of the lowermost Namurian as now defined in Europe. Faunal comparisons indicate that the Chester beds of America correspond to the *Goniatites*, *Eumorphoceras*, and possibly part or all of the *Homoceras* beds of western Europe, thus embracing uppermost Viséan and lowermost Namurian."

Precise recognition of the Viséan boundaries in North America is uncertain because ammonoid genera appear to have somewhat different ranges on the two sides of the Atlantic. Since the above-quoted statement was written, Miller has identified *Beyrichoceras* from strata of supposedly early Osagean age in southwestern Missouri. In Europe this genus is characteristic of beds equivalent in age to those which carry the lithostrotionoid coral faunas suggestive of the Meramecian. The American Meramecian is almost certainly of Viséan age, and the crinoids and brachiopods of the Osagean appear to ally this series with the Tournaisian. Consequently *Beyrichoceras* probably appeared somewhat earlier in America than in Europe.

The beginning of the Namurian in Europe is marked by the introduction of *Eumorphoceras* above the *Goniatites* zone of the Viséan. In America these genera are associated, and insofar as known at present *Eumorphoceras* is confined to lower Meramecian beds at the base of the range of *Goniatites*. Therefore *Eumorphoceras* is believed to occur in beds of Viséan age in America, and this genus cannot be relied upon to mark the Viséan-Namurian boundary line here.

Other evidence for the recognition of the upper limits of the Viséan is very scanty in America. The only beds on this side of the Atlantic that have been seriously correlated with the European section are the Mississippian formations of the Maritime Provinces of Canada. Unfortunately these strata cannot be correlated with other American formations, at present, with much confidence, and consequently correlation of the upper parts of the standard American and European sections is quite uncertain. The Viséan-Namurian boundary may correspond with the division between the Chesterian and the Meramecian, or it may fall within the Chesterian. The occurrence of *Goniatites*, which does not range above the Viséan in Europe, in strata of probably middle Chesterian age in Arkansas and Oklahoma suggests that the latter conclusion may be correct. Failure, however, of the ranges of other am-

monoid genera to correspond in Europe and America suggests the acceptance of this conclusion with clearly expressed reservations.

The position of the Mississippian-Pennsylvanian boundary in the European Carboniferous section is not clear. Moore stated (187, p. 663): "It probably corresponds to the line between the so-called Lower Namurian and Upper Namurian where a 'great paleontologic break' is recognized in the floral succession. . . ."

Jongmans and Gothan identified all but one of several collections of plants from the Pocahontas division of the Pottsville group in West Virginia as representing Middle (Upper Ostrau) or Upper Namurian zones. The one exception (123, p. 395), distinguished as typical of the Lower Namurian (Waldenburg beds), perhaps was misidentified stratigraphically and may have come from the underlying Mauch Chunk. C. B. Read informed Moore that "The Waldenburg flora is distinctively of Chester type" (187, p. 664).

Patteisky correlated the Lower Ostrau with the E zone (203, p. 720) and stated that only the uppermost part of the Ostrau formation is likely to be connected with the H zone.

Moore considered the Erzgebergian orogeny, which occurred in Europe within the Namurian and separates the R and H goniatite zones, to correspond with the break in sedimentation generally separating the Mississippian and Pennsylvanian systems in America (187, p. 671). The base of the Upper Carboniferous in Europe is placed at the Viséan-Namurian boundary, and this horizon probably occurs some distance below the Mississippian-Pennsylvanian contact and possibly corresponds approximately to the Homberg-Elvira boundary in the Chesterian Series. If so the European E and H zones may be more or less equivalent to the Elvira and "post-Elvira" groups respectively.

Differences of opinion regarding the proper lower limit of the Carboniferous are as prevalent in Europe as they are in America. Conclusions reached have generally depended upon the type of fossils considered. Thus coral students would place this boundary below the top of the Famennian (at base of Oberdevonstufe V), while others basing their conclusions on the ranges of cephalopods and plants would place the boundary above the base of the Tournaisian (at base of Unterkarbon I). Trilobites suggest that the boundary should be drawn at the base of the Tournaisian, but the evidence of brachiopods suggests the base of the Strunian (K) zone (230, p. 654). Jongmans and Gothan selected the base of the Tournaisian Z zone as the Devonian-Carboniferous boundary, although at the first Heerlen Congress the base of the Strunian (K) zone had been agreed upon (122, p. 5).

STRATIGRAPHIC PROVINCES

The Mississippian System in North America differs greatly from place to place in lithologic composition, stratigraphic succession, and faunal content, and on this basis the continent can be divided into four principal stratigraphic provinces. The eastern or Atlantic province is the smallest and occupies portions of Newfoundland, Nova Scotia, and New Brunswick. If Mississippian beds are present in the late Paleozoic metamorphics of New England, the province should probably be extended southwestward to include that area. It may also extend to east Greenland.

The Central or Interior province includes most of the eastern and central United States. Here the typical Mississippian sequence of this continent is developed, and here the System has been most intensively studied and is best known. Several subprovinces may be recognized, but in spite of variable lithologic characteristics the standard classification is applicable throughout.

The Western or Cordilleran province occupies an enormous area extending from Mexico to western Canada and includes most of the western third of the United States. Many details of stratigraphy in this region are inadequately known, and some of the correlations of formations recognized in different parts are more or less uncertain. Lithologic development is quite variable, and, if it were better known, several subprovinces undoubtedly could be distinguished.

Mississippian rocks are poorly known throughout much of the Pacific coastal belt, and if present in certain areas they constitute an unrecognized part of a great metamorphic complex. Peculiarities of the faunas here suggest that this region should be recognized as a fourth province.

Mississippian strata of the Arctic islands of northern Canada and Greenland are so imperfectly known that adequate comparison with other North American occurrences is not possible.

Interior province.—Types of sediments and the conditions under which they were deposited varied greatly from place to place and from time to time within this province. Much the greater part of the clastic sediment was derived fron the east and south where Appalachia and Llanoria were subjected to almost continuous erosion.

During some part of Kinderhookian time, as this epoch is commonly defined, black-shale deposition was extremely widespread throughout much of interior North America. In several areas these conditions were the continuation or resumption of similar conditions that prevailed late in the Devonian Period. To the northeast in Pennsylvania and adjacent States, however, coarser clastics similar to late Devonian deposits were laid down, indicating that this region was closest to Appalachia or that the neighboring part of Appalachia was higher and undergoing more severe erosion than other parts. Northern Appalachia was probably being uplifted at this time, because upper Kinderhookian clastic materials were subsequently carried greater and greater distances westward in eastern Tennessee and Kentucky and in Ohio and Michigan. To the southwest, conditions were quite different, and black shale gave way laterally to chert in Arkansas, Oklahoma, and parts of Texas. In the central and western parts of the province, beyond the reach of Appalachian sediments, upper Kinderhookian strata consist of limestone and clastics of more local derivation.

Northern Appalachia apparently continued to rise in Osagean time, and clastics from this source were distributed as far as central Illinois. Farther west, and also in the south, limestone was contemporaneously formed. In the Southeastern States and as far north as southern Illinois this limestone is extremely siliceous, but in the upper Mississippi Valley and westward and southwestward to the Rocky Mountains purer limestone with much conspicuous chert was deposited. In some large areas these beds are noted for their profusion of crinoidal remains.

In Meramecian time clastic sedimentation was relatively unimportant. Widespread limestone was deposited throughout much of the interior of North America succeeding local Osagean formations everywhere except possibly in southwestern

Texas, southern Oklahoma, and southern Arkansas, in parts of Alabama, Georgia, and Tennessee, and in part of Pennsylvania. In some of these areas Meramecian beds are largely absent or have not been identified. The eastward extension of limestone is particularly noteworthy, and Appalachia was obviously a much less important source of clastics than either earlier or later in Mississippian time. In contrast, clastics, probably derived from the north or northwest, are conspicuous in the Meramecian formations of Iowa and western Illinois, and Michigan. Associated with them are gypsum and anhydrite in beds of St. Louis age. The occurrence of evaporites also characterizes Meramecian deposits in Montana, Michigan, Virginia, and the Maritime Provinces of Canada.

Clastic sediments derived mainly from the east and south were widely distributed during Chesterian time. Chesterian seas, however, appear to have been less extensive northward than in previous Mississippian time and probably never reached the upper Mississippi Valley region of Iowa and adjacent areas or the Great Lakes region of Michigan and northern Ohio. Chesterian sedimentation was quite variable, and thin limestones separated by shales and sandstones are common. In areas farthest from the source of sediments, such as Illinois, Indiana, and western Kentucky, cyclic deposition was well developed, similar in many ways to that which was so widespread during Pennsylvanian time in this and other regions.

During the closing part of the Mississippian Period, in post Elvira time, sedimentation appears to have been still further restricted to the geosynclinal zones of the east and south, and a considerable part of the material deposited was laid down under nonmarine conditions.

In the Interior province the Mississippian is a good example of a great though complex cycle of deposition on a systemic scale starting with the clastics of the expanding Kinderhookian seas, grading through the strata of the Osagean Series into the widespread limestone deposition of Meramecian time, and reverting to clastics in Chesterian time laid down in contracting basins.

Atlantic province.—A similar cycle of systemic magnitude is clearly exhibited by the Mississippian strata of eastern Canada and Newfoundland. These begin with clastic, nonmarine, plant-bearing formations of the Horton group, followed by the partially marine and evaporite-containing Windsor group, and conclude with the Canso group, which is similar in most respects to the basal series. This province appears to have had no direct connection with the Interior province from which it was probably separated by the northern extension of the Paleozoic land mass of Appalachia.

Western province.—Few satisfactory detailed correlations have been established between the Mississippian strata of the Mississippi Valley region and those of the Rocky Mountain States. Possibly these regions were separated by a land barrier which extended southwestward from Minnesota to Colorado throughout a more or less broad zone in which Pennsylvanian strata now overlie pre-Mississippian formations in the subsurface. Direct marine connections probably existed, however, during most of Mississippian time farther to the south by way of southern Kansas, Oklahoma, and Texas to New Mexico. Apparently significant in this connection is the fact that certain New Mexican faunas resemble those of the Mississippi Valley more closely than others known in the west.

The typical lower Mississippian deposits of the west consist of a prominent and

very widespread limestone, the Madison and its equivalents, which extends from northern Alberta throughout the Rocky Mountain States and southwestward to southern California and Mexico. They probably were partially interrupted by a positive axis extending southwestward from Colorado to Arizona continuing the trend of the possible land barrier, previously mentioned. Upon this axis were located emergent areas which marked the beginnings of the Ancestral Rocky Mountains and which contributed some clastic sediments to the near-by sea. A sediment-producing land area lay to the west, and lower Mississippian limestone grades locally into clastics in this direction, particularly in central Idaho, which was probably the site of an important geosyncline.

In this same basin upper Mississippian strata are much less homogeneous, and clastic sediments alternating with limestones are characteristic and widely distributed. In this respect, the situation is similar to that of the Chesterian in the eastern half of the continent. Possibly it indicates an elevation of the western borderland and various island areas and the filling up of the bordering geosynclinal trough.

Throughout much of this region, upper Mississippian and lower Pennsylvanian deposits have not been clearly distinguished, and no important changes in type or distribution of sediments mark this systemic boundary.

Pacific province.—The relations of Mississippian strata in the Pacific coastal zone, extending from Alaska to northern California, to the deposits of the Rocky Mountain region are not clear. The restriction of the *Gigantella* fauna to the former region and the absence of Mississippian deposits in a large part of western Nevada suggest the presence of a land barrier west of the Great Basin region, and the Pacific zone is generally considered to constitute a different province.

The succession of sediments in the Pacific zone differs from that in most of the Rocky Mountain and Great Basin regions because earliest Mississippian rocks generally appear to be absent, and the basal Mississippian deposits, which may be of middle Mississippian age, are clastics and include nonmarine strata in Alaska. Throughout large areas these beds are so completely metamorphosed that their original characters are not apparent. Although little is known about Mississippian rocks in the Arctic islands of Canada, this region appears to be a continuation of the northern part of the Pacific zone.

The relations between Mississippian and younger strata are quite different here from those in the Western province. Throughout considerable parts of the Pacific province, strata of Pennsylvanian age have not been identified with certainty. At various places extending from northern California to southeastern Alaska and possibly also in the Arctic islands Permian limestone succeeds the Mississippian. Possibly strata at other places, supposed to be Pennsylvanian, may be Permian also.

FAUNAL ZONES

Many excellent guide fossils occur in the Mississippian System of North America, but only in the type area of the Interior province has a serious effort been made to zone the Mississippian strata paleontologically. A few conspicuous and easily recognized forms like *Lithostrotionella castelnaui* have long been known to be closely restricted stratigraphically, throughout wide areas, but for the most part correlations have been attempted by the percentage-species method rather than by the identifi-

cation of closely restricted species of known but limited time range. Too often, correlation by entire faunas gives conflicting results probably because of erroneous identifications or because the stratigraphic ranges of many forms have not yet been adequately determined. Much detailed and painstaking paleontologic work remains to be done in both field and laboratory before the very abundant Mississippian species can be used to best advantage in correlation.

Several well-marked faunal zones were distinguished by Stuart Weller (301). Most of these are of wide distribution in the Central States, and some of them are useful for correlations with other areas. In addition, a few other zones of outstanding importance may be recognized.

Earlier and Later Mississippian faunas.—Most earlier and later faunas of the Mississippian Period are easily distinguished, and an important change in faunas appears to occur about at the boundary between the Meramecian and Osagean series. Some difference of opinion exists regarding the abruptness of this change and its significance, but the general differences of the faunas are recognized by all.

The earlier faunas are likely to include some more robust species of several phyla, particularly the brachiopods. *Syringothyris*, which first appeared in the latest Devonian, is confined to the earlier Mississippian. Large specimens belonging to the *Spirifer grimesi-logani* group characterize a somewhat restricted zone. *Orthotetes keokuk* is conspicuously larger than *O. kaskaskiensis* of the later Mississippian. Camerate crinoids occur in some of the earlier faunas in great profusion, whereas later they become progressively rarer and are represented only by moderately sized or small species. *Griffithides* is resticted to the earlier Mississippian.

The later Mississippian faunas are particularly characterized by abundant specimens of *Composita* and *Pentremites*. Both genera occur in the earlier faunas, but nowhere are they abundant. *Pentremites* is somewhat restricted in geographic range and is rare in most of the western faunas, but *Composita* is widely distributed. *Archimedes* appears in the uppermost strata of the Osagean and is reported to persist locally into the Pennsylvanian, but it is particularly characteristic of several later Mississippian zones. Colonial corals generally are not abundant in the Mississippian, and large colonies occur only in later beds. Horn corals are abundant, but later species do not attain the size of some of the earlier ones. *Kaskia* is restricted to the later Mississippian.

Paraphorhynchus zone.—This genus is strictly limited to the Kinderhookian Series. It has been collected from the Louisiana, Bushberg, Chouteau, and Hampton formamations of the type area and from lowermost Mississippian strata in other regions. It is sporadically distributed, however, and absent from many collections. The fact that it crosses the boundary between the Fabius and Easley groups emphasizes the close relations between strata which are assigned by some to the Devonian and by others to the Mississippian system.

Leptaena zone.—This genus, which ranges upward from the Middle Ordovician, is represented in the Kinderhookian and earliest Osagean faunas. It is widely distributed in North America and is a characteristic member of the Madison fauna of the west. Although it is not known above the lower Burlington in the Central States Girty believed that its range might be more extended elsewhere.

Spirifer grimesi-logani zone.—Large spirifers of this type are particularly character-

istic of the Osagean Series although representatives of this line first appear in the upper Kinderhookian. They are widely distributed throughout North America and probably mark a zone equivalent to that of the closely related *Spirifer striatus* in Europe.

Productus (*Marginirugus*) *magnus zone.*—This species occupies a narrow zone near the middle of the Mississippian System that has been assigned variously to the Keokuk or Warsaw. It occurs widely in the southern part of the Central States but is unknown near the type localities of the formations mentioned above. The large size of this species and its association with *Syringothyris* favor a late Osagean age.

Tetracamera zone.—This zone overlaps the boundary between the Meramecian and Osagean series and embraces beds ranging from Keokuk to Salem. The Osagean species, however, are considerably larger than those occurring in the Meramecian.

Brachythyris subcardiformis zone.—*Brachythyris* is represented by several species which range through the Kinderhookian, Osagean, and Meramecian series. *B. subcardiformis*, the second largest species, is characteristic of the Warsaw and Salem formations throughout most of the Central States. *B. suborbicularis*, a much larger form, is equally characteristic of the Osagean.

Lithostrotionella castelnaui zone.—This species and *L. proliferum*, which probably has a slightly longer stratigraphic range, are the most characteristic members of the St. Louis limestone fauna. One or the other occurs, locally in great abundance in certain layers, wherever limestone of this age is present in the Central and Eastern States. Similar colonial corals, commonly recorded as "*Lithostrotion*", are of wide occurrence in the west. There they characterize certain post-Madison or later Mississippian faunas but appear to possess a much greater but unknown stratigraphic range. These western corals have not been adequately studied and may include representatives of several genera and species unknown to the east.

Platycrinites penicillus zone.—This crinoid, also known as *P. huntsvillae*, commonly has been cited as one of the principal guide species of the Ste. Genevieve limestone with a range closely paralleling that of *Pugnoides ottumwa*. Its characteristic basal calyx plates are widely distributed in that formation but also occur in some underlying strata generally referred to the St. Louis. This species is most useful for distinguishing upper Meramecian from lower Chesterian strata, and for this purpose it can be identified by dismembered stem segments. Similar stems, however, occur in beds at least as old as the Salem limestone.

Diaphragmus zone.—*Diaphragmus* is sparingly represented in the Ste. Genevieve limestone, particularly in its upper strata, but it is much more abundant and characteristic of the Chesterian faunas. Some reported occurrences of this brachiopod, however, especially in certain of the western faunas, are doubtful because other forms of small productids may have been misidentified.

Talarocrinus zone.—This crinoid, easily recognized by its peculiar basal plates, is restricted in its occurrence to the New Design group of Chesterian age, and it occurs in the Central and Eastern States in beds immediately overlying those which carry the last representatives of *Platycrinites penicillus*. A single species referred to this

genus occurs in the Warsaw-Salem, but no complete specimen has been found, and the correctness of its generic assignment is questionable.

Stenoscisma explanata zone.—This little brachiopod, formerly identified as *Camarophoria*, is an excellent guide to the post-New Design Chesterian faunas in the Central States where it is of common occurrence and wide distribution, and it appears to possess a generally similar stratigraphic range to the east. It likewise occurs in some of the later Mississippian faunas of the west, but there it is associated locally with species that suggest lower strata. The stemless crinoid *Agassizocrinus* ranges through similar strata of the later Mississippian but continues into the early Pennsylvanian.

Pterotocrinus capitalis zone.—This crinoid, most commonly represented by its isolated massive wing plates, is confined to a narrow zone in the lower part of the Golconda formation. Although an excellent index fossil, it occurs only locally in the Central and Eastern States. This zone also carries *Pentremites obesus*, the largest species of the genus, which is sporadically present in the Central states and may correspond to *P. maccalliei* of the east.

Prismopora zone.—Prismopora seratula, the only Mississippian representative of the genus, characterizes the Homberg group of Chesterian age. In some areas it is most abundant in the Golconda formation but in others it is restricted to the Glen Dean. A few specimens have been found in younger formations, but it is generally lacking in Elvira faunas. The genus recurs, represented by several other species, in the lower Pennsylvanian.

Sulcatopinna zone.—This pelecypod ranges throughout the formations of the Elvira group but is most abundant and widespread in the Menard limestone of the Central States. It also occurs at an uncertain but possibly comparable position in the east.

Millerella zone.—This primitive representative of the fusulinids occurs in the youngest strata of the Chesterian Series in the Central States and in some probably equivalent beds of the west. Its range, however, continues into the lower Pennsylvanian.

Spirifer centronatus zone.—This species, originally described from Michigan but rarely identified subsequently in the Central States, has been commonly cited as a characteristic member of many earlier Mississippian faunas of the west. Many of these identifications appear doubtful. The specimens so named resemble *Spirifer vernonensis* and other similar species of the Mississippi Valley which occur in Kinderhookian and lower Osagean strata.

Gigantella zone.—These large productids are known only in the far west and Alaska and mark a fauna of strong Asiatic affinities. Correlations with other American faunas are unsatisfactory, but the *Gigantella* zone is probably of approximately Meramecian age.

Leiorhynchus zone.—In the past, certain correlations have been made on the basis of specimens identified as *Leiorhynchus carboniferum* from wide-spread localities extending from Alabama to Alaska. It is fairly evident, however, that these brachiopods do not characterize a limited zone but occur at various levels in the Meramecian and Chesterian series. Although they are not certainly known in the lower

Mississippian, similar forms are present in the Upper Devonian. Apparently this genus is characteristic of a certain type of dark shale environment rather than of any particular restricted time.

AMERICAN MISSISSIPPIAN AMMONOID ZONES[1]

Much more consideration has been given to Lower Carboniferous or Mississippian ammonoid zones in Europe than in America, particularly by Bisat in England, Delépine in France, Schmidt (and Wedekind and Schindewolf) in Germany, and Librovitch in Soviet Russia. However, as early as 1903, J. P. Smith ably compared and contrasted the various faunas known at that time (243). More recently, Plummer and Scott have noted the occurrence of two Mississippian zones in north-central Texas (208, p. 14); in 1940 Miller and Furnish published a comparison of European Middle Carboniferous faunal zones and certain American ammonoid-bearing beds in Arkansas, Oklahoma, Texas, Nevada, Kentucky, and Georgia (178); and in 1944 Gordon reported on the ammonoid zones of the Moorefield, Ruddell, and Batesville formations of Arkansas (96).

Clearly the American Mississippian ammonoids need to be thoroughly restudied in the light of modern paleontological investigations, but three ammonoid zones, with rather indefinite borders, can be recognized tentatively in the Mississippian System. These should be termed the zones of *Protocanites*, *Beyrichoceras*, and *Goniatites*, respectively. The zone of *Protocanites* is more or less equivalent to the Kinderhookian, the zone of *Beyrichoceras* to the Osagean, and the zone of *Goniatites* to the Meramecian and the Chesterian (Fig. 2). In Europe the zone of *Pericyclus* comes between the zone of *Protocanites* and that of *Beyrichoceras*; but three of the four specimens of *Pericyclus* known from America were found in association with *Protocanites*, and the fourth came from an assemblage which is strikingly similar to that which occurs with *Protocanites*. *Tornoceras* has been reported from beds that some have believed to be early Mississippian, but no valid representatives of that genus have been found in strata known to be younger than Devonian.

Zone of Protocanites.—The ammonoids of this zone are perhaps known best from the Rockford limestone of Indiana, which carries representatives of *Imitoceras*, *Munsteroceras*, and *Prodromites*, as well as *Protocanites*. All of these genera (and *Gattendorfia*) occur also in the Chouteau limestone of central Missouri, along with *Pericyclus*; three of them (*Imitoceras*, *Munsteroceras*, and *Protocanites*) and *Gattendorfia* are represented in the Northview shale of southwestern Missouri; both *Imitoceras* and *Protocanites* have been described by Williams from the Louisiana limestone of northeastern Missouri; and a single representative of the former genus (*Imitoceras*) has been found in the Hannibal shale, which overlies the Louisiana. Also, *Prodromites* occurs in the Kinderhookian of west-central Illinois; both it and *Imitoceras* are known from the Hampton formation of southeastern Iowa; and in Michigan *Imitoceras* has been found in the Coldwater shale and in the Marshall group—in addition the latter carries *Munsteroceras* and *Protocanites*. To the east, *Protocanites* occurs in association with *Imitoceras* in the Cuyahoga group of Ohio and in association with *Munsteroceras* in the lower part of the Price formation of southwestern Virginia;

[1] This section was contributed by A. K. Miller.

at both these localities the containing beds are almost certainly Kinderhookian in age, though some authors have regarded them as Osagean (38). Recently *Pericyclus* and *Gattendorfia* have been collected from the Caballero formation of south-central New Mexico, where they occur in a large and varied fauna that is strongly reminiscent of the Chouteau.

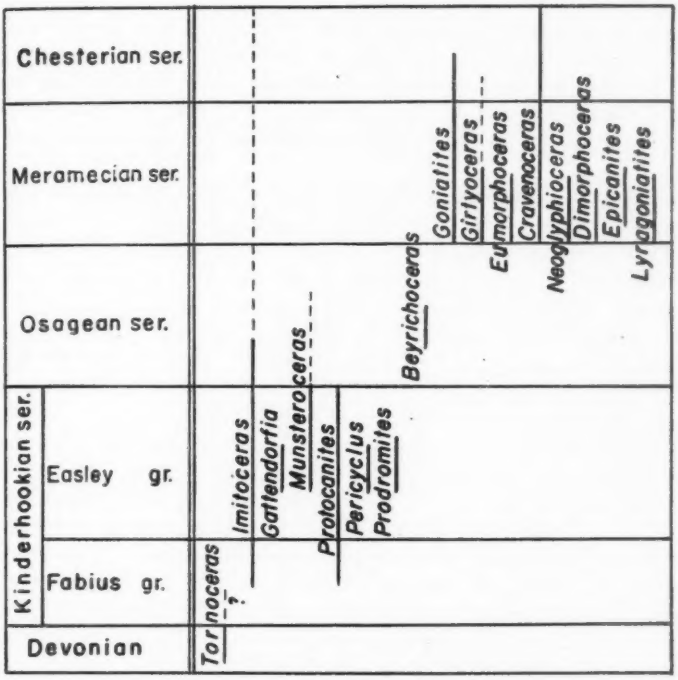


FIGURE 2.—*Known probable ranges of Mississippian ammonoid genera*
Data furnished by Miller

In Europe an assemblage of ammonoids that is quite similar to the one in the Kinderhookian strata has long been known from the Tournaisian of Belgium and equivalent beds in Ireland and Germany (Schmidt's zones I and IIα). Rather recently certain of the characteristic genera have been described from Soviet Russia and China (Kazakhstan and the Tian-Shan Mountains) by Librovitch and from northern Africa (Morocco and Algeria) by Menchikoff and Delépine.

Zone of Beyrichoceras.—The formations in North America that immediately overlie the *Protocanites*-bearing beds, the Osagean Series, carry very few ammonoids. However, *Imitoceras* is known from the Fern Glen formation of western Illinois; several specimens that are probably referable to *Munsteroceras* have been described from the Burlington limestone of central and northeastern Missouri; and one or two goniatites of uncertain affinities have been listed from the New Providence shale of

Kentucky and Indiana. Finally, a typical representative of *Beyrichoceras* has recently been found in the lower part of the Boone formation of southwestern Missouri. At least insofar as sutures are concerned, this specimen resembles closely the genotype of *Beyrichoceras*, *B. obtusum* (Phillips), from the Pendleside limestone of northern England. In Europe *Beyrichoceras* is characteristic of the middle Viséan (Bisat's zone B and Schmidt's zone IIIα). Thus it seems possible that the Osagean formations are of about the same age as the middle (and possibly also the lower) Viséan of Europe, where ammonoids are not particularly rare at certain localities. In 1941 Delépine described *Beyrichoceras* and some other goniatites from Morocco. The age of the fauna that K. K. Chao described in 1940 from central Hunan, China, is uncertain, but it may well have come from beds that are equivalent to part of the Viséan.

Zone of Goniatites.—In western Europe, where Middle Carboniferous ammonoid zones have been given careful consideration, the genus *Goniatites*, s. s., is represented in only the Viséan; that is, in northern England it occurs in Bisat's *Beyrichoceras* (B) and *Posidonomya*[2] (P_1 and P_2) zones and in Germany it ranges through Schmidt's IIIα-γ zones. *Girtyoceras* appears to have essentially the same range (B–P_2 and IIIα-γ). *Eumorphoceras* is stated to be limited to the next higher zone or zones (E_1–E_2 and IVα-δ), that is, to the Lower Namurian. Therefore, in 1940 Miller and Furnish attempted to distinguish a zone of *Goniatites* and one of *Eumorphoceras* in the Upper Mississippian goniatite-bearing beds of North America. However, in 1909 Girty had indicated a questionable association of *Goniatites* and *Eumorphoceras* in the Caney shale of Oklahoma, and in 1937 Plummer and Scott had listed both of these genera as occurring in "a thin layer of limestone in the Barnett shale" of north-central Texas. Furthermore, Miller has studied representatives of these two genera that Cooper and Cloud found in direct association in the Barnett. It therefore seems clear that in this hemisphere these genera were at least in part contemporaneous.

Perhaps the best American sequence of goniatite-bearing strata of this general age is in Arkansas. There *Goniatites* makes its debut in the Moorefield and ranges up through the overlying Ruddell shale and Batesville sandstone into the "Mayes" limestone of the lower part of the Fayetteville formation. It has not, however, been found in the upper Fayetteville or in the overlying Pitkin limestone, both of which have yielded only a very few goniatites. Unfortunately, *Eumorphoceras* seems to be entirely unknown in this Arkansas sequence, with the possible exception of a single poorly preserved specimen of uncertain affinities which Girty illustrated and described in 1911 (92, p. 103) from the Ruddell shale ("Moorefield shale", as then delimited).

Elsewhere in this country, *Goniatites* is known from the Floyd shale of Georgia, the upper Mississippian of Kentucky, the Caney shale of Oklahoma, the Barnett shale of north-central Texas, and the Helms formation of west Texas. In most of these, it has been found in association with such other goniatite genera as *Girtyoceras* and to a lesser extent *Cravenoceras*, *Neoglyphioceras*, and *Dimorphoceras*. Representatives of certain of these genera have also been secured from the White Pine shale of Nevada and the Heath formation of Montana.

In the eastern hemisphere, comparable goniatite faunas have been recorded from

[2] In part synonymous with *Caneyella*

the British Isles, numerous localities in western Europe, Menorca, northern Africa, European and Asiatic Soviet Russia, and Indo-China. Certain species described from the Caney shale of Oklahoma are strikingly similar to those found in England, a fact stressed by Bisat.

Faunal relations.—Most of the groups of ammonoids that are used to zone the Devonian became extinct before the beginning of Carboniferous time, and only two stocks cross the Devonian-Mississippian boundary. One of these, the prolecanitids, became quite diverse in the Mississippian, and they have a considerable amount of stratigraphic value there, but their descendants, the pronoritids, and the daraelitids continued through the Pennsylvanian with little change. The other Devonian stock that continued into the Mississippian is represented by the genus *Imitoceras*. It underwent great development during Carboniferous time and gave rise to many diverse forms. Certain of these, for example the dimorphoceratids and the agathiceratids, had become fairly well established by the end of the Mississippian Period, but others, notably the gastrioceratids, underwent a great deal of development during the following period. Descendants of the gastrioceratids, therefore, include some of the most useful ammonoids for Late Paleozoic stratigraphic correlation.

Although *Imitoceras* is not rare in the Devonian of Eurasia and Africa, no representatives of it have been found in the American Devonian. Furthermore, the youngest European Devonian ammonoid zone seems to be essentially unrepresented in this country. As a result, the latest Devonian and earliest Mississippian ammonoid faunas of America are quite distinct and are not known to have even a single genus in common. However, part of the Kinderhookian faunas, representatives of the genera *Imitoceras* and *Munsteroceras*, seems to have continued into the Osagean with very little change, and the only other genus known from the Osagean, *Beyrichoceras*, is very similar to *Munsteroceras*. It is of course true that only a few ammonoids are known from the Osagean, but none of them is at all similar to Meramecian forms. The latter, however, are very closely related to those in the Chesterian, and there is more or less transition between the American Mississippian and Pennsylvanian ammonoid faunas, and roots of most of the Pennsylvanian stocks can be recognized in such late Mississippian faunas as that known from the Caney shale and equivalent strata. Thus it is evident that the chief breaks in the ammonoid faunas under consideration occur just below the Kinderhookian and just above the Osagean, and if one were dealing with ammonoids alone he would certainly group the Osagean with the Kinderhookian and not the Meramecian.

AMERICAN MISSISSIPPIAN CRINOID ZONES[1]

In North America crinoids occur prolifically in Kinderhookian and Osagean rocks, and very complete evolutionary series can be traced. At the end of the Osagean many genera and some whole families become extinct. Survivors in the Meramecian and Chesterian rocks are much less numerous, diverge widely from older forms, and show remarkable advances in evolution. They are more closely allied with the succeeding Pennsylvanian crinoids than with those of the Osagean (Fig. 3).

[1] This section was contributed by L. R. Laudon

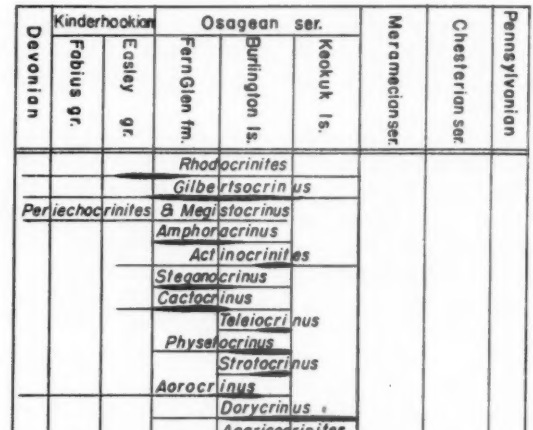


FIGURE 3.—*Ranges of important Mississippian crinoid genera*
Data furnished by Laudon

The Rhodocrinitidae are the only representatives of the dicyclic camerates (Diplobathra) that occur in Mississippian rocks. *Rhodocrinites* is abundant in the late Kinderhookian, diminishes rapidly in importance in the Osagean, and did not survive into the Meramecian. *Gilbertsocrinus*, the only other Mississippian rhodocrinitid genus, is most abundant in the Osagean and absent from the Meramecian.

The Periechocrinitidae are feebly represented in Mississippian rocks with two

genera, *Periechocrinites* and *Megistocrinus*. Both occur abundantly in the older Paleozoic rocks and did not survive the Osagean.

Amphoracrinus (Amphoracrinidae) occurs exclusively in rocks of early Osagean age and does not range into the Keokuk.

The Actinocrinitidae are prolifically represented in rocks of late Kinderhookian and Osagean age, and none survived into the Meramecian. *Actinocrinites*, the most primitive genus, first appears in the Chouteau formation. Kinderhookian species are generally small. Osagean species develop tubular arm projections as in *A. multiradiatus* and *A. verrucosus*. Heavy ponderous forms such as *A. lowei* occur in upper Osagean rocks. *Steganocrinus*, a close relative, occurs first in rocks of early Osagean age and ranges through the Burlington, but does not occur in the Keokuk. *Cactocrinus* appears first in rocks of late Kinderhookian age, occurs prolifically in lower Osagean strata, but only one species, *C. glans*, survived into the upper Burlington and Keokuk. *Teleiocrinus*, a specialized offshoot from *Cactocrinus*, occurs throughout the Burlington formation but is most abundant in the upper part; it is not found in the Keokuk. *Physetocrinus* occurs first in rocks of early Osagean age, ranges through the Burlington formation, and died out before the beginning of the Keokuk. *Strotocrinus*, a specialized offshoot from *Physetocrinus*, is limited to the Burlington and occurs prolifically in the upper part of that formation.

The Desmidocrinidae are represented by three Mississippian genera. *Aorocrinus*, a primitive survivor from the Devonian, ranges through the Burlington and is absent from the Keokuk. *Dorycrinus*, a specialized offshoot from *Aorocrinus*, occurs first in the early Osagean and is prolific in both the Burlington and Keokuk. *Agaricocrinites* ranges throughout the Osagean and is most abundant in the Keokuk. None of these genera survived into the Meramecian.

The Batocrinidae, derived from the Desmidocrinidae, appear first in rocks of early Osagean age. They became abundant during Burlington time, diminished rapidly in importance in the Keokuk, and are unknown in the Meramecian or Chesterian. *Batocrinus*, *Eretmocrinus*, *Macrocrinus*, and *Uperocrinus* range throughout the Osagean. *Eutrochocrinus* appeared in the Burlington and is also present in the lower Keokuk. *Dizygocrinus* occurs first in the upper Burlington and becomes prolific in the Keokuk. *Alloprosallocrinus* is limited to Keokuk rocks.

The Dichocrinidae, offshoots from the Devonian hexacrinids, occur abundantly throughout the Mississippian. *Dichocrinus* ranges throughout the system, and some of its species are of index value. *Talarocrinus* and *Pterotocrinus* are particularly important because they are limited to Meramecian and Chesterian strata. The Acrocrinidae, specialized offshoots from the Dichocrinidae, are rare. They range throughout the Mississippian but in general were much more abundant in the later part of the period.

The Platycrinitidae occur in great abundance in Kinderhookian and Osagean rocks and are occasionally found in the upper Mississippian. *Eucladocrinus*, a specialized platycrinitid, is limited to the Osagean.

Flexible crinoids are not abundant in Mississippian faunas except in the late Osagean. Among the Sagenocrinitidae, *Forbesiocrinus* is the most abundant genus and is limited to the late Kinderhookian and Osagean. Two genera of the Synero-

crinidae, *Dactylocrinus* and *Euryocrinus*, both survivors from the Devonian, range through Kinderhookian and Osagean strata. *Wachsmuthicrinus* is limited to the Osagean. Three genera, *Amphicrinus*, *Artichthyocrinus*, and *Ainacrinus*, occur only in the Chesterian.

The Taxocrinidae are more useful as index fossils in the Mississippian because they are more common than other flexible crinoids. *Taxocrinus*, a survivor from the Devonian, ranges throughout the entire Mississippian but is most abundant in Kinderhookian and Osagean beds. *Onychocrinus*, an offshoot from *Taxocrinus*, also ranges throughout the entire Mississippian but is most abundant in the late Osagean.

Inadunate crinoids are common in the Mississippian and in general appear to have longer ranges than the more specialized camerates. They are particularly valuable in Meramecian and Chesterian strata where they are the most abundant crinoids.

Monocyclic inadunates (Disparata) are not common. In the Calceocrinidae only one genus, *Halysiocrinus*, survived to the end of Osagean time. The Allagecrinidae are best represented; *Hybochilocrinus* occurs only in the Kinderhookian; *Catillocrinus* and *Eucatillocrinus* occur with particular abundance in Fern Glen—St. Joe strata and did not survive the end of the Osagean; and *Allocatillocrinus*, derived from *Catillocrinus*, ranges through the Mississippian and into the Pennsylvanian. In the Synbathocrinidae, several species of *Synbathocrinus* range to the end of Osagean time when they became extinct.

Dicyclic unadunates (Cladoidea) are particularly valuable index fossils in Meramecian and Chesterian rocks where they occur abundantly. Because of the large number of genera, only important ones are mentioned. *Lasiocrinus*, *Goniocrinus*, and *Gilmocrinus* are the only genera confined to Kinderhookian rocks. None is abundant. *Gilmocrinus* ranges into the late Viséan of Scotland.

Many dicyclic inadunate genera are abundant in the Osagean but do not occur in younger strata. Particularly important are *Barycrinus*, abundant in the Burlington rocks; *Poteriocrinites*, abundant in Fern Glen, St. Joe, and Lake Valley beds; and *Blothrocrinus*, *Cercidocrinus*, *Eratocrinus*, and *Decadocrinus*, abundant in both the Kinderhookian and Osagean. *Scytalocrinus* and *Abrotocrinus* characterize the late Osagean, particularly beds of Keokuk age.

Very few dicyclic inadunates are restricted to the Meramecian. *Culmicrinus* ranges from late Kinderhookian through the Meramecian where it is abundant. *Dinotocrinus* and *Phacelocrinus* appear first in Meramecian strata and continue into the Chesterian.

Dasciocrinus, *Tholocrinus*, *Pentaramicrinus*, *Phanocrinus*, *Eupachycrinus*, *Agassizocrinus*, and *Anartiocrinus* appear first in rocks of Chesterian age. *Phanocrinus* and *Agassizocrinus* are particularly abundant and widely distributed.

A few dicyclic inadunate genera such as *Cyathocrinites*, *Linobrachiocrinus*, and *Graphiocrinus* range throughout the Mississippian.

Crinoids have been used much more extensively for zonation of Mississippian formations in North America than for Lower Carboniferous rocks in Europe. The work of Bather, De Koninck, and more recently Wright has made possible close comparisons of British sections with those of America on the basis of crinoids. The

Tournaisian crinoid fauna from the Coplow beds (C_1 zone of Vaughn) contains genera such as *Actinocrinites*, *Amphoracrinus*, and *Gilbertsocrinus* which characterize upper Osagean beds in North America. Viséan rocks (C_2 to D_3 zones of Vaughn) carry forms characteristic of the American Meramecian and lower Chesterian. The unique Scottish Carboniferous crinoid fauna described in Wright's classical monograph (329), rich in such genera as *Woodocrinus*, *Hydreionocrinus*, *Ulocrinus*, *Phanocrinus*, *Anemetocrinus*, and *Synerocrinus*, is characteristic of the later portion of the Chesterian.

AMERICAN MISSISSIPPIAN FLORAL ZONES[4]

Because of scarcity of specimens and their generally poor preservation, the Mississippian floras of North America have been neglected, and comparatively little has been published on this subject. David White, however, recognized two floras in the Appalachian region (309). The lower occurs in beds of the Pocono-Price group (or series) and in strata of equivalent age in the Maritime Provinces of Canada and the Arctic. It is characterized by the presence of *Triphyllopteris*, *Adianites*, *Sphenopteridium*, *Rhodea*, and lycopods of the "*Lepidodendron*" *corrugatum* type. This flora is rather sharply distinguished from the underlying Catskill flora, as *Triphyllopteris* is unknown in the Upper Devonian, and *Archaeopteris* does not range into the Lower Mississippian (3, p. 50).

The upper flora occurs in the Mauch Chunk group (or series) and is also known in certain Chesterian strata of the Central States. It is characterized by *Lepidodendron volkmannianum* or closely related forms, *Stigmaria ficoides stellata* (possibly roots of these same plants), and *Asterocalamites scrobiculatus*. Calamarians, of which the latter is an example, are very rare or absent in the early Mississippian, and *Calamites* did not appear until very late in Mississippian time. Also the earliest neuropterids are first encountered in strata of youngest Mississippian age.

These two contrasting floras appear to be separated by an interval roughly equivalent to the Meramecian, from which practically no plants are known in North America.

In addition to the foregoing, two other floras of somewhat doubtful age require consideration. One of these occurs in black shale at the junction of the Mississippian and Devonian systems. It is marked by the wide-spread but sporadic occurrence of *Callixylon* generally referred to the species *C. newberryi* (2). This plant occurs in both the Devonian and questionably Mississippian portions of the New Albany shale of Indiana and Kentucky, and also has been reported from Ohio and Michigan; another species has been described from the Woodford chert of Oklahoma. Somewhat similar stems, with structure resembling *Callixylon*, have been found in middle Mississippian limestone in southwestern Missouri (52). Also associated with the black shale in central Kentucky, but actually in beds immediately above it, occurs a unique flora partially described by Read (215). Because certain specimens were believed to represent the Psilophytales he referred this flora unequivocally to the Devonian. However, such typical early Carboniferous genera as *Pitys*, *Lepido-*

[4] C. A. Arnold has aided in the preparation of this section.

dendron, *Cladoxylon*, and *Clepsydropis* also are present and throw considerable doubt on this age assignment.

The other doubtful flora has been collected from the Stanley and Jackfork formations of the Ouachita Mountains (10). This flora contains no species known to be exclusively characteristic of the Mississippian, but also it is different from the oldest Pennsylvanian assemblages and finds its closest parallel in the flora of certain European strata that are now referred to the Lower Namurian. Other European beds of supposedly comparable age carry goniatites that are present in the American upper Mississippian, and thus, very indirectly, late Mississippian age is suggested for the Stanley and Jackfork. If this conclusion is correct, there is still little doubt that the flora is distinctly younger than that which is typical of the Chesterian.

In many respects, the late Mississippian flora appears to be directly ancestral to the succeeding Pennsylvanian flora, and there does not seem to be so sharp a distinction at this systemic boundary as at the Devonian-Mississippian contact.

Possibly, however, these similarities result from a better knowledge of the floras and the probability that plants lived under more nearly comparable conditions of environment. The absence of *Pecopteris* from Mississippian floras and its common occurrence in the Pennsylvanian is one of the more important differences between the plant assemblages of these ages.

PROBLEMS OF NOMENCLATURE

A geologic formation may be defined most briefly as a "mappable unit", and it is generally agreed that a formation need not be of exactly the same age everywhere it is recognized (4, p. 1075). No sharp distinction can be made in stratigraphy between a formation and a group (which consists of two or more formations) on the one hand or between a formation and a member (which is a subordinate part of a formation) on the other. In different areas or in the same area at different times approximately the same sequence of beds might be designated a group, a formation, or a member (219, p. 6). As more detailed geologic investigations are completed it is natural that a larger number of more restricted formations should be recognized. As an example, the name St. Louis was used rather indiscriminately for many years as the designation of either a formation or a group, more or less equivalent to the present Meramecian Series, which variously included or excluded the beds now known as Warsaw. Later, with the recognition of the Salem (or Spergen) and Ste. Genevieve formations, the St. Louis was restricted within its present limits. In a somewhat different manner the long-recognized Madison limestone was subdivided into Paine, Woodhurst, and Castle members, then raised to the rank of group composed of Lodgepole (Paine and Woodhurst) and Mission Canyon (Castle) formations.

Both of the foregoing are examples of the finer discrimination of formations, but in the first the meaning of the name was radically changed, whereas in the second it was not. There may be excellent and compelling reasons for the restriction and redefinition of a formation, but confusion may result because such restriction may not be recognized by all geologists, and a single stratigraphic name may be understood and used quite differently by different contemporary authors. For example, the

Mississippian System in Alabama was divided into two formations by Smith (241, p. 155), the Fort Payne chert below and an upper formation named Bangor where it is dominantly limestone. Subsequently the Bangor was restricted by Butts (34, p. 195) to beds between the Hartsell sandstone (probably Hardinsburg) and the Pennington shale, making it equivalent to the Glen Dean of the type region plus a variable thickness of Upper Chesterian where the latter is dominantly limestone. For the lower major part of the original Bangor he introduced the name Gasper from Kentucky. A different interpretation was made by Sullivan (259, p. 21) in which the Gasper and Hartsell were not recognized, and the name Bangor was applied to all beds between the Fort Payne chert and Pennington shale, including strata ranging in age from St. Louis to Glen Dean or younger. Thus the name of a restricted formation may have no precise significance unless it is accompanied by the name of the author who used it, the date, and the locality where the name was used.

Inspection of the correlation chart shows that some formation names have been very widely applied. If the formations in question can be recognized throughout wide areas all will agree that this is desirable because stratigraphic nomenclature and classification are thereby simplified. Certainly anyone who has engaged in the compilation of an extensive correlation chart soon is faced by the many uncertainties connected with the comparison of numerous different stratigraphic successions consisting of an amazing multiplicity of formations. Superficially the solution of this difficulty may appear to be the wide extension of a comparatively few formation names, but under many circumstances other complications will be introduced that are more insidious because they are less apparent.

Many of the formations recognized today had very small beginnings. Commonly, names were proposed after studies in very restricted areas without adequate definition, description of boundaries, or exact designation of type localities. Later the usage of these names spread as the formations were recognized elsewhere on the basis of continuity, lithologic characteristics, or faunal content. Generally, recognition was dependent upon lithologic peculiarities and variations in the stratigraphic sections of neighboring areas, or on paleontologic correlations between more distant areas.

The widespread recognition of formations on the basis of continuity and lithologic similarity and the correlation of beds on the basis of paleontology are processes familiar to all geologists. They are, however, fundamentally dissimilar and may produce distinctly different results. Unfortunately these differences are commonly overlooked, and there is a general tendency among geologists to assume that strata known by the same formation name in various areas should be of exactly the same age and, conversely, that strata of the same age in various areas should be known by the same formation name. Neither of these assumptions, however, is justified. Because both methods have been used in the recognition of formations at places distant from their type areas, considerable confusion now exists regarding the proper application and meaning of numerous formation names.

A good example of a formation that has been widely identified almost exclusively on a lithologic basis is the Chattanooga shale recognized at one time or another in Georgia, Alabama, Tennessee, Kentucky, Illinois, Arkansas, Missouri, Kansas, and

Oklahoma. This formation is now known to include beds of quite different ages at different places. In contrast the St. Louis limestone is recognized principally on the basis of paleontology in Georgia, Alabama, Mississippi, Tennessee, West Virginia, Kentucky, Indiana, Illinois, Missouri, and Iowa. Throughout this area it cannot be distinguished from adjacent formations by any consistent lithologic means. Although it always includes the "*Lithostrotion*" zone its boundaries are drawn at locally convenient lithologic changes which probably vary considerably in their time significance from place to place.

The names of some formations have been extended into outlying areas because beds of similar age (included between underlying and overlying beds that had been correlated with some show of confidence) were believed to be present even though the beds in question neither resemble the typical formation lithologically nor contain a convincingly similar fauna. The Spergen or Salem limestone of Iowa and parts of western Illinois is a formation of this kind.

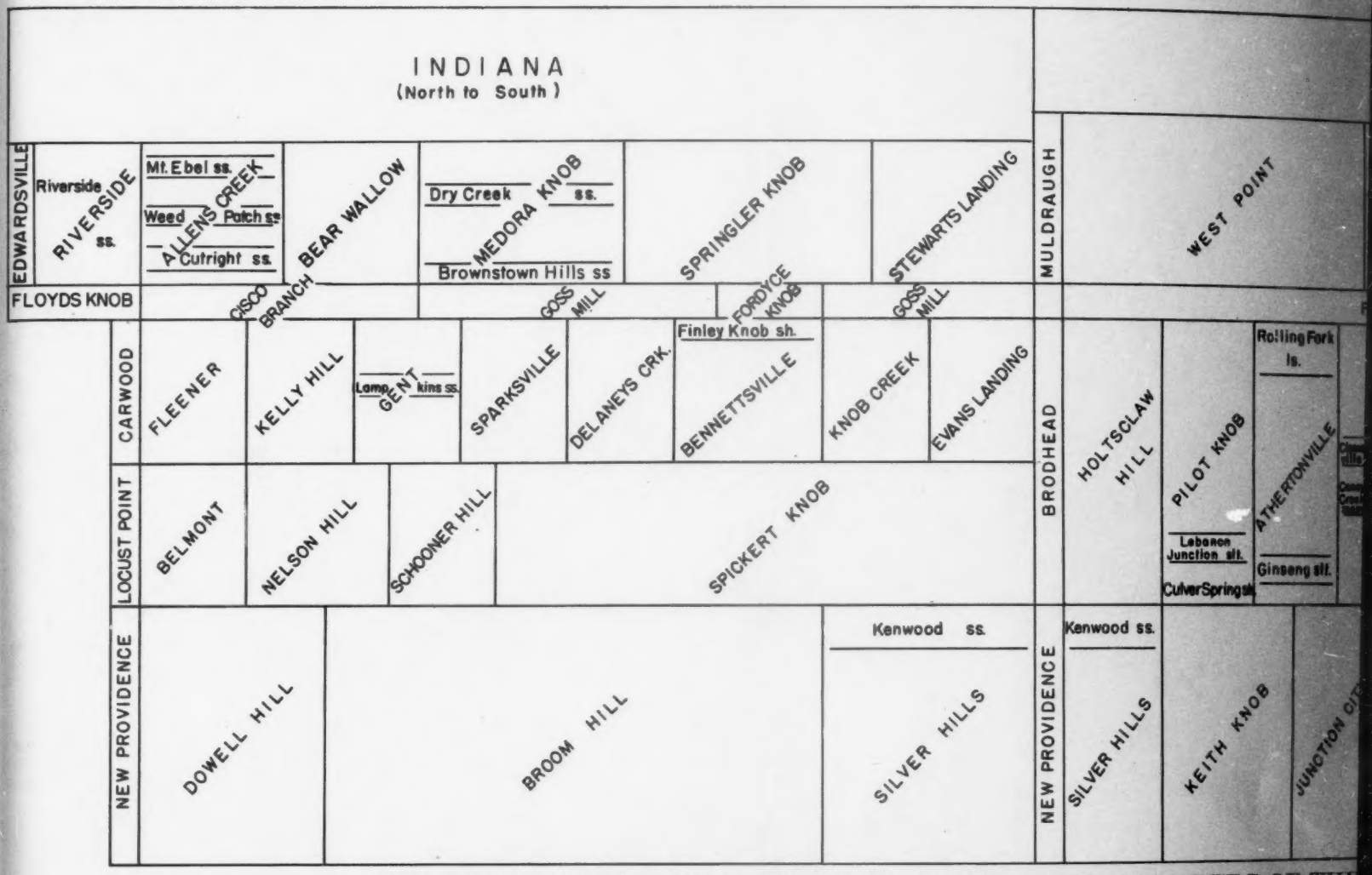
Other formations closely defined lithologically and carrying more or less distinctive fossils in their type areas have had their names extended into regions where similar faunas occur but where even approximately equivalent strata have not been distinguished. For example, the name Glen Dean has been applied to beds in Virginia which are six to seven times as thick as the formation in its type area and are neither underlain nor overlain by strata that can be correlated reasonably with the formations that bound the original Glen Dean.

Finally, there are formations, like the Gasper "oölite," consisting of such various strata, as recognized at different places, that their names have little meaning unless accompanied by a reference to the author, date, and locality. The Gasper generally is not lithologically distinguishable from the Ste. Genevieve. Everywhere it includes beds of Paint Creek age, it may or may not be extended downward to include beds of Renault and Levias ages, and it may or may not continue upward to include beds as young as Golconda.

Obviously the development of a satisfactory system of stratigraphic nomenclature is attended by many perplexing difficulties, particularly when it has grown through the unco-ordinated publications of many geologists whose interests, opinions, and experience are quite dissimilar. For many years the Committee on Geologic Names of the United States Geological Survey has been concerned with this problem, but its decisions are binding only on members of the Federal survey. Some of the Committee's decisions have appeared to be arbitrary and ill-considered to local geologists, who have had no voice in its proceedings.

The variable thickness, distribution, and paleontologic and lithologic characters of strata of similar age present permanent problems that must be met by any system of stratigraphic classification and nomenclature. Other current problems, however, appear to result from the conflict of time-stratigraphic versus rock-stratigraphic interpretations, and they will persist as long as the matter of formational nomenclature is approached from these divergent viewpoints.

In order to be useful a formation must be reasonably easy to identify, and reasonably easy to distinguish from adjacent formations in every area where it is recognized. Such identification and distinction commonly depend upon physical peculiarities and



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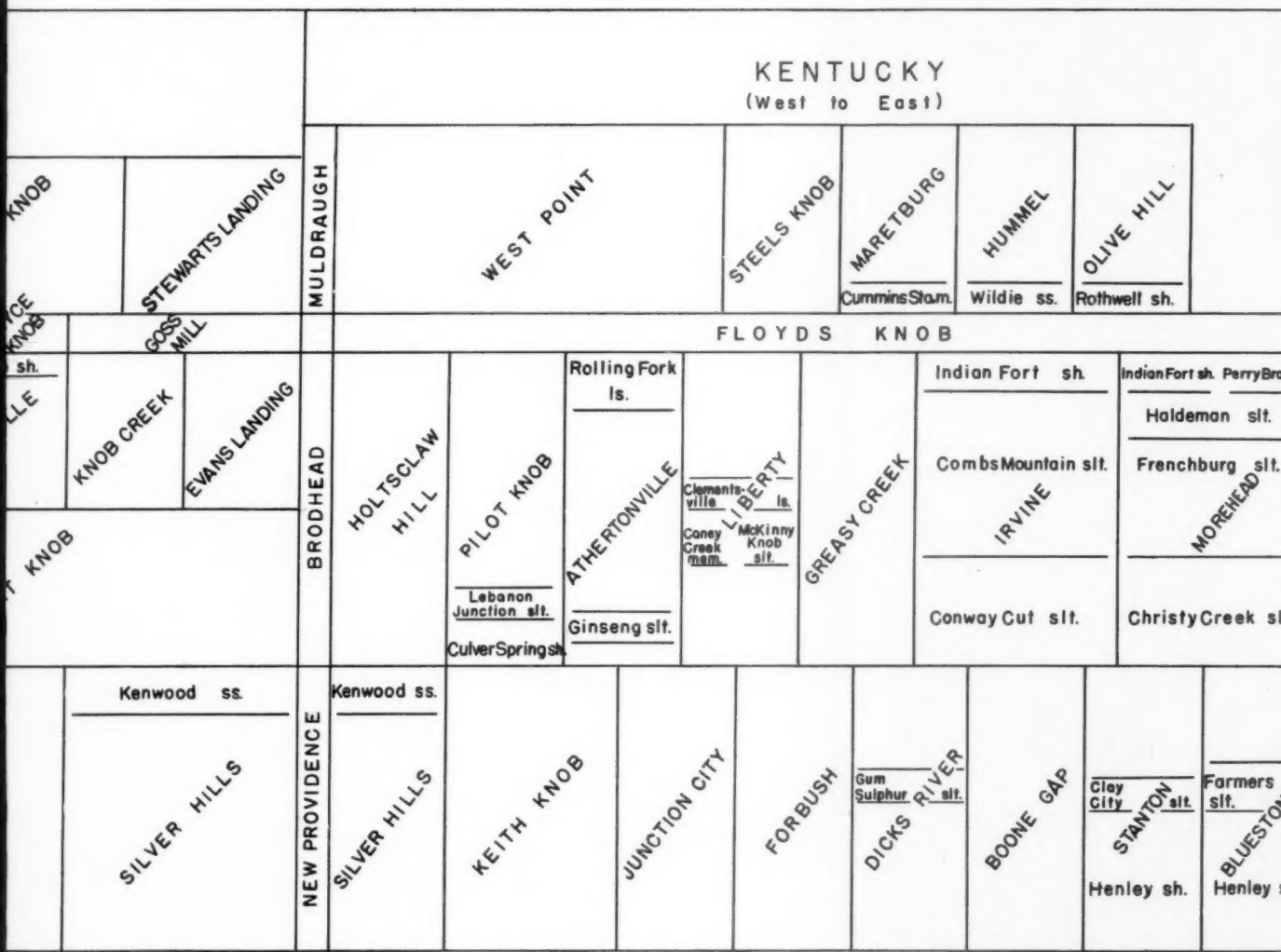

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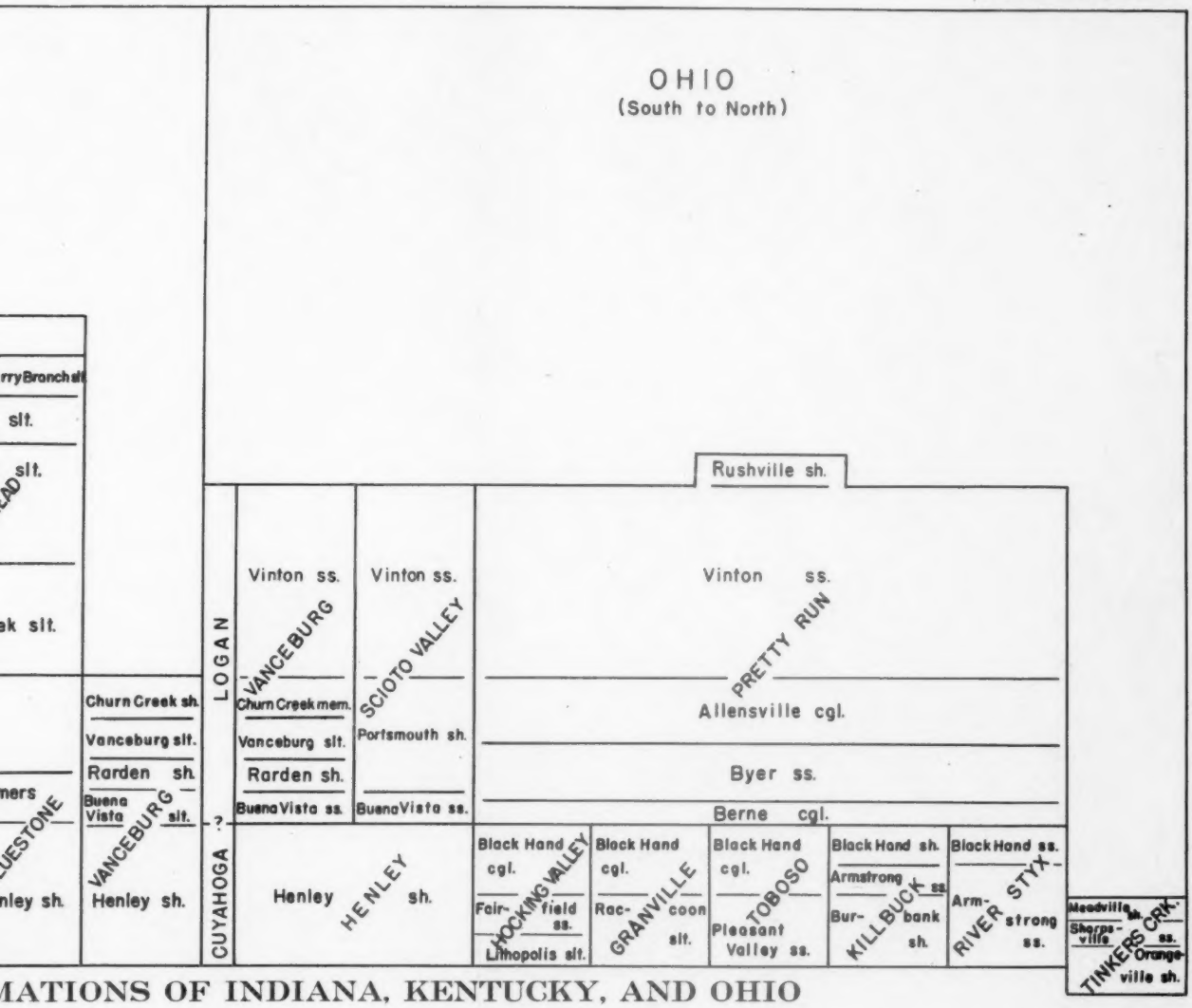

MATIONS OF INDIANA, KENTUCKY, AND OHIO

variations. If every formation were accepted as a convenient lithologic unit and extended only as far as is lithologically reasonable, and without actual or implied time limitations (190, p. 527), which is not true for many formations at present, a sound basis for local geologic studies understandable by all would be provided, and the details of correlation could be made the responsibility of paleontologists (229, p. 1420). There is, however, increasing tendency for geologists with strong paleontologic leanings to define or redefine formations on the basis of faunal zones. Some of these zones, undoubtedly, are of wide extent and of great stratigraphic significance, but others, because of unrecognized facies relationships or other deficiencies of knowledge, are of very questionable value. Many of them cannot be identified by persons without the paleontologist's special skill, and paleontologists are likely to disagree among themselves or change their minds regarding both alleged facts and interpretations. Consequently, if this practice is not discontinued many formations may lose some of their practical usefulness, and increased instability of nomenclature is likely to result.

FACIES NOMENCLATURE

Facies variation is not peculiar to the Mississippian System, but the problems which result from certain types of rapid lateral variation in sediments, in the fields of both practical stratigraphy and stratigraphic nomenclature, have received more attention in the lower Mississippian and upper Devonian rocks of Ohio, Pennsylvania, Indiana, and Kentucky than in other parts of the stratigraphic column and other regions of the continent (Pl. 1). The work of Hyde (116), Stockdale (253; 254), and Chadwick and Caster (46) is particularly important.

Both Hyde and Stockdale recognized certain major formations each of which, they presumed, was deposited contemporaneously throughout its entire extent. Each formation was then divided vertically into different facies developments which were given geographic names. Finally the facies were divided horizontally into members which were also partially or completely named. This system has proved to be flexible and convenient for description. The facies names are, in effect, synonyms of the formation names but have only local significance. Although this system introduces a large number of names, many of them can be ignored by persons having no interest in the detailed stratigraphy of these formations.

Caster was more concerned with the interrelationships of rock-stratigraphic and time-stratigraphic units. To units of more or less uniform lithologic characters which transgress time lines he applied the term magnafacies; these are rock-stratigraphic units and correspond to the original lithologic formations of the northern Appalachian region. He used the terms stage, formation, or stratigraphic unit for time-stratigraphic units. The magnafacies and stages intersect each other, and for the intersected strata Caster introduced the term parvafacies. According to this system, which is an elaboration of conclusions reached earlier by Chadwick and others, each magnafacies consists of a succession of parvafacies of similar lithologic character but unequal age, and each stage consists of a succession of parvafacies of similar age but different lithologic character. Geographic names were introduced for all so that

strata at any place have three major names: a more or less local parvafacies name, and extensive magnafacies, and stage names. In addition, named members are also recognized. This system is of considerable theoretical interest and may be very useful in the detailed study and description of the strata deposited near the margin of an expanding delta. It is not likely, however, to be widely applicable to other types of facies problems.

ALASKA

Rocks of known or probable Mississippian age occur in all of the principal subdivisions of Alaska except the Alaska Peninsula and Aleutian Islands. Over large areas they are mainly either of igneous origin or so metamorphosed that most fossils have been destroyed or are so poorly preserved that definite age determinations are impossible. At some places, however, a few well-preserved specimens have been obtained from small areas of less strongly metamorphosed sediments. Because of the great size of Alaska, the wide separation of areas of Mississippian rocks, and the preliminary nature of much of the geologic investigations, many local formation names have been proposed. Also, in several areas, Mississippian rocks are included with rocks of other ages in more or less long-ranging formations or groups.

Northern Alaska; Column 1.—Two Mississippian formations have been distinguished in the Cape Lisburne region, but because of complicated structure their exact stratigraphic relations are not known. *Leptaena analoga* has been identified from the lower part of the coal-bearing Noatak formation which has consequently been referred to the Lower Mississippian as Osagean or older. Girty, however, tentatively identified this species locally in the western United States where it occurs associated with others suggestive of post-Osagean age. However, fossil plants studied by David White were assigned by him to the Lower Mississippian, and he stated that they probably belonged to the "basal part of the Lower Mississippian" (244, p. 166; 308, p. 146).

The Noatak appears to be overlain by the Lisburne formation which has been recognized at various places in northern Alaska from Cape Lisburne eastward to the International Boundary, and rocks in various other areas have been correlated with it. This chert-bearing limestone carries a large fauna, including corals belonging to the Lithostrotionidae and related families, bryozoans of the *Fenestrellina cestriensis* type, and brachiopods similar to *Spirifer striatus* and *Productus* (*Diaphragmus*) *elegens* (165, p. 311). These and other forms strongly suggest that the formation is of Meramecian and younger age.

In the Canning River area, the Lisburne formation is underlain by unfossiliferous black shale and sandstone, originally referred to the Mississippian or Upper Devonian (156, p. 106). These strata are lithologically similar to part of the Noatak formation and are tentatively correlated with it.

A somewhat similar stratigraphic succession has been reported by Maddren and others near the 141st Meridian. Fossils identified as lithostrotionoid corals, *Productus* (*Gigantella*) *giganteus*, *Moorefieldella*, and certain bryozoans indicate the presence of the Lisburne limestone, and black slates and shales in the lower part contain both invertebrate and plant fossils, suggesting early Mississippian age.

Poorly preserved corals examined by Williams indicate the probable presence of Mississippian strata in the York district of the Seward Peninsula.

Yukon Valley, Column 2.—Rocks of known or probable Mississippian age occur in the Yukon Valley at various places from the International Boundary to near the river's mouth. Although best known along the Yukon River, there is a large area of Mississippian rocks in the region enclosed between the upper Yukon and Tanana rivers. Because of complex structure, the stratigraphic relations of the various recognized formations are rarely observable, and the succession shown on the chart is composite and not altogether certain.

Fossils are rare and rather undiagnostic in the Livengood chert. Mertie's opinion of its age (176, p. 110) was based as much on the absence of species rather common in the Upper Devonian of Alaska as on those specimens which have been obtained from the Livengood. Some fossils have been collected at various places from undifferentiated beds that in general appear to be younger than that formation, but local correlations have been based mainly on lithologic similarities. Most of these specimens are poorly preserved and give little evidence as to age except that they are Mississippian. Possibly the Wellesley formation, of only local recognition, belongs in this part of the section.

Fossils are also very rare in strata of the Rampart group, which locally includes much extrusive volcanic material. The overlying Calico Bluff formation contains a large fauna that is now being studied. Included in it are *Leiorhynchus carboniferum*, *Moorefieldella*, and other brachiopods suggestive of early Meramecian age, but both older and younger beds may be included. Girty believed this formation to be "upper Mississippian, roughly correlative with the Chester group of the United States" (176, p. 139). Presumably it is younger than any of the other strata mentioned above.

The age of the Nation River formation, generally believed to be younger than the Calico Bluff but nowhere observed to overlie it, is doubtful, although it is generally referred to the Pennsylvanian. This formation is not known to contain fossiliferous marine strata, and David White dated a few poorly preserved plants obtained from it as Mississippian or Devonian (176, p. 144). Because of lithologic similarities, including the presence of coal, others have been inclined to correlate these beds with the Noatak formation (176, p. 145).

The stratigraphic section in the Wiseman-Chandalar area is reported to be similar to those of the Canning River and Porcupine-International Boundary regions. Possible Mississippian rocks in the Koyukuk-Melozi and Marshall areas are largely lava flows and tuffs and unfossiliferous metamorphic rocks.

Southwestern Alaska, Column 3.—The Tikchik formation, although unfossiliferous, has been referred to the Mississippian because of its stratigraphic position below known Permian beds (245, p. 33). Strata in the Goodnews area formerly referred questionably to the Carboniferous are now believed to be Permian on the basis of a few brachiopods identified by Girty (245, p. 33).

Copper River Region, Column 4.—Rocks of Mississippian age may occur extensively

in the Copper River region, but if present they are predominately metamorphic and igneous, and few identifiable fossils have been obtained from them. Numerous local names have been proposed, and the relationships between these units are little known. Undoubtedly several of them include rocks referable to more than a single geologic system (182, p. 23).

Although very poorly preserved, the most varied fauna has been obtained from the Strelna formation. These fossils are Carboniferous, but they cannot be definitely identified as Mississippian (182, p. 28). A fauna from the Chisna formation studied by Williams indicates that these beds are partly, if not entirely, Permian. The Klutena group consists mainly of metamorphic rocks and has furnished no diagnostic fossils. Brooks considered it to be Carboniferous, but its actual age is not known. Similarly the Valdez, Orca, and other groups are largely metamorphic and igneous and have yielded no fossils or only a few specimens too poorly preserved to be of stratigraphic significance.

Alexander Archipelago, Column 5.—Fossiliferous Mississippian limestones occur on Chicagof, Kuiu, Prince of Wales, Suemez, and other islands of southeastern Alaska (26, p. 40). Two formations have been distinguished by Williams, but they have not been named. The lower is very cherty and contains the coral fauna of the Lisburne formation and brachiopods similar to *Productus* (*Gigantella*) *gigantea* and *P.* (*Linoproductus*) *ovatus*. It is believed to be no older than Meramecian. The upper limestone is less cherty and lighter-colored. Its correlation is complicated by the association of Mississippian species with other fossils generally considered to be indicative of the Pennsylvanian. Girty noted similar associations in the western United States, but as yet their significance is not well understood. Kirk believes that crinoids from some beds currently classed as Mississippian are actually of Pennsylvanian age (137, p. 110).

Mississippian rocks are also probably present on the adjacent mainland, but metamorphism appears to have destroyed all fossils. Buddington considered that much of the Wrangell-Revillagigedo belt of metamorphics is probably Carboniferous (26, p. 73), and similar rocks described by the Wrights in the Ketchikan district may also be partly Mississippian (328, p. 56).

PACIFIC COAST

The oldest sedimentary rocks of the Pacific coastal region consist principally of thick and widespread metamorphics which are variously interrupted by both extrusive and intrusive volcanics. Their age is very uncertain. They may be in part pre-Cambrian, but the rare occurrence of fossil fragments demonstrates the Paleozoic age of some of these strata. Possible Mississippian fossils have been identified from these metamorphic rocks at few places, but Mississippian strata are probably present, at least locally, because beds of this age are known from Alaska to Mexico only a short distance inland from the coast.

Yukon Territory, Column 6.—Metamorphic rocks correlated in a general way with the Cache Creek Series of British Columbia have been termed the Yukon (155, p. 10)

or Mount Stevens groups. The latter has been restricted in some areas to the older metamorphics, and younger beds have been referred to the Taku (55, p. 12) and Perkins groups. The age of these rocks may range from pre-Cambrian to Permian, and Mississippian beds are probably present. However, they have not been carefully studied, and the relations of beds in different areas and the ages of different parts of the sequence are very inadequately known. The Braeburn limestone, locally recognized, has yielded a few fragmentary fossils of supposed Mississippian age (154, p. 12).

British Columbia, Column 7.—The Cache Creek metamorphic series is widely distributed in British Columbia, and it has likewise been recognized in Yukon Territory and in Washington. This name has largely supplanted other "group" and "series" names that have been used more locally. The upper part, in which limestone may be conspicuous, is of Permian age (66, p. 160). Mississippian beds are probably present in the middle or lower parts although lack of fossils has rendered definite identification impossible.

Washington, Columns 8–10.—Many names have been used in local areas for the metamorphic and igneous rocks of this State which are probably of Paleozoic age (68, p. 52). The San Juan Series, divided into the Orcas group below and the Leech River group above, contains Permian or Pennsylvanian fusulinids in its upper part (171, p. 111), and its middle part has been referred to the Mississippian although no fossils of that age have been found. Similar rocks probably occur in the neighboring part of British Columbia (232, p. 439). The Sicker Series is probably equivalent to part of the San Juan, but it may not include Mississippian beds. The Newaukum series, known only to be pre-Tertiary, may be in part Mississippian. The Stevens Series, divided into several named members, has fusulinids in its upper part and fossils that are probably Mississippian in older zones although Girty and others believed some of these to be Devonian (16). The Covada, correlated with the Cache Creek, may include Mississippian beds, but fossil evidence (202, p. 33) is uncertain, and Culver believes it to be older. The Pend Oreille Series is, at least in part, equivalent to the Stevens and may be partly Mississippian (281, p. 50). The Hawkins formation is generally considered Carboniferous and may be in part or wholly Mississippian. The Peshastin formation formerly referred to the Carboniferous (279, p. 26) has been more recently correlated with beds containing Trenton fossils (246, p. 560). The Gun Peak formation contains fusulinids (279, p. 38), and the Anarchist Series has yielded a few fossils that are probably Permian (278, p. 1364), but both might also include beds of Mississippian age. The Kruger and probably equivalent Chopaka schists may be Mississippian or younger.

Oregon, Columns 11, 12.—The Coffee Creek formation of central Oregon comprises the only definitely recognized Mississippian beds in this State. Its fauna includes the productids *Gigantella* and *Striatifera*, *Spirifer* like *S. striatus*, and lithostrotionoid corals (175, p. 151). This is a fauna of strong Asiatic affinities known from northern Alaska to California and probably is of Meramecian age or younger. Elsewhere

Mississippian rocks are generally believed to be absent except possibly in a few small areas mostly in the eastern and southwestern parts of the State (246, p. 86). If present, they are much metamorphosed and have yielded no certainly diagnostic fossils. Metamorphic rocks in southwestern Oregon have been considered in part Carboniferous (282, p. 1396), but some of these are now referred to the Mesozoic on the basis of fossils studied by Reeside (304, p. 1938).

Klamath Mountains, California, Column 13.—The late Paleozoic sequence in the Klamath Mountains is best known in the Redding area where two formations are recognized (110, p. 283). The Bragdon, widely distributed in the southern part of the mountains, contains *Spirifer* aff. *striatus*, lithostrotionoid corals, and other less distinctive forms. The overlying Baird shale is more limited in distribution and has yielded similar fossils and in addition *Spirifer* aff. *centronatus*, *Gigantella*, and other productids. These faunas contain no distinctive Chesterian species, but it is not unlikely that deposition of the Baird shale continued into Chesterian time. Wheeler correlated this formation with the Upper Dinantian of Europe (306, p. 409). Both formations include extrusive volcanic rocks. The Bragdon contains the Bass Mountain basalt, and several beds of rhyolitic and andesitic types are present in the Baird.

Sierra Nevada, California, Columns 14–16.—The Calaveras formation or group, generally referred to the Mississippian, occurs widely in the Sierra Nevada and consists of metamorphosed sedimentary and igneous rocks. In most places it is the only late Paleozoic formation recognized and undoubtedly it has served as a catch-all. Fusulinids reported from its upper part at some places demonstrate the Pennsylvanian or Permain age of these beds, and possibly it also includes Triassic strata although Taliaferro doubts this. Likewise the lower part of the formation may be locally Devonian or older. In the Taylorsville area, it has been divided into sevaral formations (78, p. 4). Fusulinids reported from the Shoofly indicate that this is at least as young as Pennsylvanian (78, p. 23). In the Colfax area, the Calaveras was divided into five formations. Fossils from the uppermost or Clipper Gap and lowermost or Blue Canyon formations identified in 1900 (158, p. 2) suggest that the entire sequence there is of Mississippian age. Later two additional formations, the Tightner and Kanaka, were introduced between the Blue Canyon formation and Relief quartzite in the near-by Allegheny district (87, p. 6). Elsewhere the Calaveras has not been subdivided. In the Kernville area, metamorphosed sediments that may be all or only partly equivalent to the Calaveras have been known as the Kernville Series (180, p. 352).

Central Coast Range, California, Column 17.—Mississippian rocks may be included in the Sur Series (217, p. 64) of highly metamorphosed sedimentary and volcanic rocks, but Taliaferro believes that this series is probably all older than Carboniferous (263, p. 121).

Inyo Range, California, Column 18.—Girty's identification of *Eumorphoceras* and

Caneyella from the White Pine shale indicates that parts at least of this thick formation, correlated with the Caney shale of Oklahoma (135, p. 38), are of later Mississippian age. More recently, large White Pine collections have been made, but identifications of these fossils have not yet been published.

Nopah Range, California, Column 19.—Two members of the Monte Cristo limestone have been distinguished in the Nopah and Resting Springs quadrangles, and they have been correlated tentatively with the section at Goodsprings, Nevada. Fossils, including *Spirifer* cf. *grimesi* and *Leptaena*, from the lower member suggest early Osagean age (105, p. 336). This formation overlies the Stewart Valley limestone whose fossils were identified by Kirk and G. A. Cooper as Mississippian, and Hazzard believed the latter to be equivalent in part to the Valentine and Crystal Pass limestones of Goodsprings, Nevada, which had been referred previously to the Devonian (105, p. 334). A similar stratigraphic section has been reported in the Providence Mountains of San Bernardino County (106).

Death Valley, California, Column 20.—The presence of Mississippian beds in the Argus and Panamint ranges of Inyo County has been determined on the basis of stratigraphic work by Hopper and paleontologic studies by Girty, but no formations have been distinguished or named (113). Possibly beds of this age are included in the Death Valley formation of Murphy (193, p. 350). Fossils collected by Noble and others in the Funeral Range and elsewhere have been determined to be Mississippian by Girty and Williams.

San Bernardino Mountains, California, Column 21.—Poorly preserved brachiopods from the Furnace limestone were determined by Girty to be Carboniferous and probably Mississippian (323, p. 270).

Los Angeles, California and southward, Column 22.—The discovery of a cyathophyloid coral in marble at Winchester west of the San Jacinto Mountains is basis for the conclusion that the Mississippian may be represented there (283), and lithologically similar rock in the Placerita formation of the San Gabriel Mountains may be of similar age (324, p. 255) although W. J. Miller believed this formation to be pre-Cambrian. The Julian Series near San Diego formerly thought to be of possible Carboniferous age is now believed to be younger (79, p. 340).

INTERCORDILLERAN REGION

Mississippian rocks occur at numerous places in the intermontane States of Nevada, Utah, and Arizona, but careful studies have been restricted largely to more or less isolated areas, and most of the lithologic formations recognized locally have not been widely traced. Nevertheless, paleontologic studies by members of the United States Geological Survey and others indicate the general interrelations of these formations fairly satisfactorily.

Goodsrpings area, Nevada, Column 23.—The three lower members of the Monte Cristo limestone are approximately equivalent to the Madison of the Rocky Mountains. This part of the formation contains a *Spirifer centronatus* fauna, but the upper members have not yielded distinctive fossils (109, p. 19). The underlying Crystal Pass member of the Sultan limestone has generally been referred to the Devonian, but Hazzard and Mason (105, p. 331) expressed the opinion that it is probably Mississippian. No beds of Chesterian age have been identified in the Goodsprings area, but Girty is reported to have recognized the presence of a Chesterian fauna in the Indian Springs member of the Bird Springs formation in the near-by Spring Mountains where other Mississippian strata also occur (162, p. 1203).

Muddy Mountains, Nevada, Column 24.—The Rogers Spring formation of this area carries the *Spirifer centronatus* fauna of the Madison limestone (161, p. 30), and the overlying Bluepoint limestone has yielded a small fauna believed by Williams to be post-Madison but pre-Chesterian.

Pioche district, Nevada, Column 25.—Both the Bristol Pass and Peers Spring formations contain Madison limestone faunas, the Scotty Wash quartzite has furnished no diagnostic fossils, and the lower part of the Bailey Spring limestone was determined by Girty to be Chesterian although the upper and greater part of the formation is Pennsylvanian (305, p. 23).

Ely district, Nevada, Column 26.—Beds in the Ely or Robinson district correlated with the White Pine shale have been separated into three formations. Fossils from the Chainman shale were referred to the Upper Mississippian (probably Meramecian or early Chesterian of present usage) by Girty (250, p. 27). Specimens from the near-by Nevada mining district obtained from beds lithologically similar to the Joana limestone have been determined by Williams to be of Madison age (225, p. 302).

Eureka district, Nevada, Column 27.—The Mississippian section of the Eureka district has long been considered to consist of the White Pine shale, originally referred to the Devonian, and overlying Diamond Peak quartzite. The type localities of these two formations, however, are separated by about 40 miles, and their relations are not definitely known. Merriam believes that they are in part laterally transitional and include beds of Devonian age (174, p. 45). The White Pine shale contains beds correlated by Girty, on the basis of their fossils, with the Caney shale of Oklahoma. Ammonoids described by Miller and Furnish from beds in the Snake Mountains, which are probably equivalent to part of the White Pine or Chainman, may be of Chesterian age (178, p. 373). The Diamond Peak quartzite was originally referred to the Pennsylvanian, but the study of new collections from sections measured by Nolan and Williams and the restudy of old collections by Williams has confirmed more recent suggestions that this formation also is of Late Mississippian age.

Northern Nevada.—Mississippian strata are present at various places in northern Nevada, as in the Ruby Mountains, and near Elko, Cobre, Wills, and Mountain City.

Mostly they are present in small and disconnected areas. Considerable field work has been done in this region, but reports have not been published.

Southwestern Utah, Column 28.—The Mississippian section here is comparable to that in northern Arizona, and the Redwall limestone has been recognized at various places. This formation is generally correlated with the Madison limestone (218, p. 56), but some younger strata may be included in its upper part.

The Homestake limestone of the Iron Springs district was originally referred to the Carboniferous. The only fossils discovered in it are a few pelecypods, not specifically identifiable (157, p. 37). More recently the formation has been dated as probably Late Jurassic (198, p. 158).

San Francisco district, Utah, Column 29.—The Topache limestone bears a fauna believed by Girty to be somewhat younger than Madison (28, p. 36), but Williams, who has re-examined a portion of the collections, states that some are typically Madison, although others may be slightly younger.

Gold Hill district, Utah, Column 30.—A considerable sequence of Mississippian strata overlies the Madison limestone as recognized in this district (197, p. 24). The Woodman formation is mostly of Osagean age, but Meramecian strata probably are present in its upper part. The Ochre Mountain limestone is of Meramecian and Chesterian age. The Manning Canyon limestone contains Chesterian fossils in its lower portion and Pennsylvanian fossils above, and therefore transgresses the systemic boundary, but because of its lithologic continuity it is, nevertheless, a useful mappable unit.

Northwestern Utah.—Little has been published on the Mississippian rocks of this region. The Madison limestone here overlies the Devonian, and Brazer beds may also occur although they are not known to have been recognized.

Oquirrh Mountains, Utah, Column 31.—A thick sequence of Mississippian strata overlies typical Madison limestone with the *Spirifer centronatus* fauna in the Stockton-Fairfield quadrangles (89, p. 7). Fossils from the Deseret limestone suggest Meramecian age, and this formation is probably equivalent to part of the Brazer. Specimens from the Humbug also appear to be Meramecian. *Diaphragmus* is reported to occur in the Great Blue, and consequently this formation is probably of Ste. Genevieve or Chesterian age. The Manning Canyon limestone, here as elsewhere, contains both Mississippian and Pennsylvanian assemblages.

Tintic district, Utah, Column 32.—The Gardner dolomite contains a typical Madison limestone fauna. It overlies the Victoria quartzite which has been referred to the Lower Mississippian although it is unfossiliferous (159, p. 39). Known faunas from the Pine Canyon and Humbug formations are meager and not certainly diagnostic.

Central Wasatch Mountains, Utah, Column 33.—The Madison limestone of the

Cottonwood-American Fork district possesses a typical *Spirifer centronatus* fauna. The overlying Deseret limestone has been identified only on lithologic grounds. The Humbug formation, as recognized here, has yielded *Diaphragmus elegans* and consequently probably includes beds somewhat younger than those referred to this formation elsewhere (43, p. 28).

The Madison, Deseret, Humbug, and Great Blue formations have been identified in the Provo and adjacent areas by A. A. Baker and others.

The Deseret and Humbug formations have recently been distinguished in the Tabiona area of the Uinta Mountains by Bast and others in strata formerly referred to the Brazer (316, p. 610).

The Reed (or Reade) and Benson formations are approximately equivalent to the Brazer and Madison respectively, although it is not certain that boundaries between these formations correspond.

Northern Arizona, Column 34.—In this region, and also in southwestern Utah, all Mississippian strata are referred to the Redwall limestone. As originally proposed, this formation included beds considered to be of Pennsylvanian age that have since been transferred to the overlying Supai formation and are now referred to the Permian (195, p. 56). In general, the Redwall limestone is equivalent to the Madison. It has been zoned at several places (98; 256, p. 512). The lower part is almost certainly Kinderhookian (probably Upper Kinderhookian), and lower Osagean strata are present in the middle part. Beds of Keokuk age are believed to be absent in some areas, although they have been reported in others, and strata as young as St. Louis may occur locally as suggested by the occurrence of lithostrotionellid corals (115). No beds of Chesterian age are known in this region.

Southern Arizona, Column 35.—Beds equivalent to the Redwall and Madison in southern Arizona are known as the Escabrosa limestone. Stoyanow has stated that this region was separated from the area to the north by an old highland (257, p. 1272), but in parts of central Arizona it is difficult to decide which name should be used. The Escabrosa carries the *Spirifer centronatus* fauna typical of the western Lower Mississippian and probably ranges upward to the Burlington and perhaps higher locally. This formation is overlain by the Paradise formation which appears to range from about St. Louis to Middle Chesterian in age (107, p. 660) and is found in the southeastern part of the State.

Other names have been applied locally to Mississippian strata in southeastern Arizona. The Tornado limestone of the Globe district is now divided between the Escabrosa limestone and the Pennsylvanian (256, p. 507). The Modoc and the lower part of the Tule Springs limestone of the Clifton-Morenci district carry the *Spirifer centronatus* fauna and are of early Mississippian age.

Northwestern Sonora, Column 36.—An incompletely exposed Mississippian section occurs near Rancho Bisani, which appears to parallel that occurring in southeastern Arizona. The lower part, known as the Represo[5] beds, carries fossils reported by G. A. Cooper to resemble the Chouteau fauna of the Mississippi Valley and the Lake Valley fauna of New Mexico. Arellano reports the occurrence of many corals includ-

ing lithostrotionoid forms. These strata are probably equivalent to part of the Escabrosa limestone. The upper part, known as the Venada[5] beds, contains *Rhipidomella dubia* and is believed to be of approximately Ste. Genevieve age. It probably represents part of the Paradise formation.

Northeastern Sonora.—Beds corresponding to the Escabrosa limestone have been recognized at several places in northeastern Sonora (118, p. 1731; 262, p. 16). The section here is probably similar to that developed in the neighboring part of Arizona.

ROCKY MOUNTAINS

The Rocky Mountains begin with the Brooks Range in Alaska, extend southeastward across Canada and the United States, and, with interruptions, continue as the Sierra Madre Oriental of Mexico. The Mississippian rocks of the Brooks Range have been discussed in the section devoted to Alaska. Faunally, they appear to be related more closely to Asiatic and certain Pacific coast formation that to strata of similar age in the Rockies proper.

Little is known about Mississippian rocks in the Rocky Mountains of Yukon and northern British Columbia except that they are locally present. South of the Laird River, however, the stratigraphic section seems to be similar to that in Alberta.

Mississippian formations in most of the Rocky Mountain region were established and are identified largely on a lithologic basis, and some of them are recognized throughout very wide areas. Fossils from many places have been identified and they furnish evidence for correlations that are generally satisfactory in this region. Few descriptive paleontological studies have been published, however, and many western fossils have probably been misidentified as Mississippi Valley species. Certain western fossils appear to have stratigraphic ranges somewhat different from those of similar species in the Central States and occur in different associations. Also zonational studies have not distinguished such thin stratigraphic units as in the type region. Thus precise correlations of most western formations with the standard section is somewhat uncertain. Finally, because their limits are generally defined lithologically, there is lateral intergradation between parts of some western formations, and other boundaries as generally recognized do not correspond precisely in age from place to place.

Southwestern Alberta, Column 37.—The Banff shale and Rundle limestone constitute most of the Mississippian succession of this province. These formations are distinguished lithologically and appear to be conformable (276, p. 152). Thickening of the Banff shale westward suggests that younger beds are included within the formation in that direction. Black shale formerly considered the basal part of the Banff (275, p. 22) is now known as the Exshaw shale assigned to the Upper Devonian by Warren (277). *Tornoceras* has been collected from this shale, and C. L. Cooper reports that it has also furnished a conodont fauna of middle New Albany age. Such

[5] Names suggested by Arellano.

an association is of great interest and indicates that this supposedly diagnostic Devonian ammonoid may occur in strata of earliest Mississippian age. Similar shale present at this stratigraphic position in Montana and elsewhere in Alberta contains conodonts of late New Albany age (61, p. 172), and possibly more than one black shale zone occurs in this region.

The Madison *Spirifer centronatus* fauna is present in both the Banff shale and lower part of the Rundle formation. Several subzones of more or less wide distribution have been recognized (275, p. 29). The lowest, occurring in the middle of the Banff shale, is characterized by *Spirifer cascadensis*. The upper part of the same formation carries a fauna including a *Spirifer* identified as *S. grimesi*. The index species of the lower part of the Rundle limestone is *Spirifer rundlensis*. All of these zones appear to correspond in age with the Madison limestone. High in the Rundle limestone occurs a fauna with many corals, including lithostrotionoids, *Diaphragmus*, and *Pentremites*. This is a characteristic western Upper Mississippian fauna, similar to that in the Brazer formation to the south.

Fossils referred to Pennsylvanian species have been reported from the Rundle limestone in southern Alberta (237, p. 5; 276, p. 33), and it has been believed that the formation may transgress the systemic boundary. This conclusion, however, requires further consideration. Northward, the Rundle limestone thins, and the upper faunal zones are absent, suggesting unconformable overlap by the Rocky Mountain quartzite, although physical evidence of such an unconformity has not been noted.

Strata apparently equivalent to part of the Rundle have been termed Wardner limestone in the Purcell Range of British Columbia (231, p. 55).

Northwestern Montana, Column 38.—Mississippian limestone that had been termed Madison for many years but contains both Madison and Brazer fossils has been named Hannan formation (75, p. 1135) and divided into five named members (74, p. 46). These members appear to be recognizable only locally, and more recently the section has been subdivided into four unnamed units (240). The so-called Silvertip conglomerate, which was considered the basal member of the Hannan, is an evaporite-solution breccia probably produced by the removal of thick beds of Devonian anhydrite which resulted in the slumping of overlying strata (240). The upper part of this section carries lithostrotionoid corals, and similar beds in the Galton Range unassociated with other Mississippian sediments have been named Yakinikak limestone.

Southwestern Montana, Column 39.—The Madison limestone, one of the most widespread stratigraphic units of the western United States, was named from the Madison Range, but Sloss and Hamblin state that no satisfactory type section is exposed there and describe a section at Logan which they propose as the type locality (239, p. 313). Originally described as a formation, the Madison is now considered to be a group at many places and is divided into the Mission Canyon and Lodgepole formations largely on lithologic grounds. These beds are characterized by the *Spirifer centronatus* fauna and are believed to comprise strata of late Kinderhookian and Osagean age. Although many paleontologists have studied collections from the Madison, they have

not agreed in their conclusions, and no satisfactory detailed correlations with the Mississippi Valley section are yet possible. Younger strata are also included in the Madison locally in various areas.

The Sappington sandstone, which locally underlies the Madison, has been referred to the Upper Devonian by some (240) and to the lower Mississippian by others (10, p. 14). Perry reports that it appears to grade both vertically and laterally into the Devonian Three Forks shale and is overlain by black shale of the Lower Mississippian.

Beds overlying the Madison limestone in this and other areas have been referred to both the Amsden and Quadrant formations. As recognized for many years, these formations are approximately equivalent and include both Mississippian and Pennsylvanian strata. Because they are convenient for mapping and well-log correlation they will probably continue to be recognized as units in some areas. More recently the proposal has been made to restrict the Quadrant to beds equivalent to the Tensleep sandstone of Wyoming, which is believed to be of Pennsylvanian age, and employ Amsden for underlying strata (233). As so fixed, the latter includes the youngest Mississippian beds of this region, but in addition some believe that lower Pennsylvanian strata are also present in it (234).

Strata including black shale, red beds, and gypsum directly overlie the Madison locally in southwestern Montana and are believed by Perry to be equivalent to some part of the Big Snowy group. Possibly they should also be correlated with the Sacajawea of Wyoming.

Central Montana, Column 40.—The Mississippian sequence in this region is the most complete in the State, and the Big Snowy group, originally described as consisting of three formations, intervenes between the Madison and Amsden (206). The Heath and Otter formations contain fossils of Chesterian age with which *Leiorhynchus carboniferum* is associated, but correlations with individual formations of the type sections are not possible. The Big Snowy group as a whole appears to correspond fairly closely to the Brazer formation and probably ranges from Meramecian to at least Middle Chesterian age (233, p. 1029).

The Charles limestone, known only in the subsurface, lies between the Mission Canyon limestone (formerly known as the Castle member of the Madison) and the Kibby formation. It has been referred to the Big Snowy group (235, p. 1420), although some aspects of its lithology ally it more closely with the Madison (207, p. 6), and beds of similar age may be included in the Madison in some areas of outcrop.

The Lodgepole limestone of the Madison group is separated into the Paine and Woodhurst members. Black shale, generally considered the basal part of the Paine, carries Upper Kinderhookian fossils (61) and will probably be distinguished in the future as a separate formation possibly equivalent to the Exshaw shale of Alberta.

This succession is widely present in the subsurface of eastern Montana and has been recognized in the subsurface of western North Dakota (235, p. 6).

Central Idaho, Column 41.—Westward from Montana, rocks of Mississippian age pass into a geosynclinal facies dominated by thick dark shale. Strata of this type have been termed the Milligen formation (227, p. 968). Fossils are very scarce but

include poorly preserved plants and imperfect invertebrates among which *Leiorhynchus carboniferum* has been tentatively identified. The age range of the typical Milligen is very uncertain. Recent studies have shown, however, that strata included in the lower part at some places are of Threeforks (Devonian) age. Elsewhere Brazer fossils have been found in the upper part, and in some areas strata identified as Brazer overlie the Milligen as locally recognized.

Southeastern Idaho, Column 42.—Here, and in the neighboring parts of Utah and Wyoming, the Mississippian sequence consists of two formations—the Madison, and the Brazer above it (169, p. 60). Distinction has been made generally on a lithologic basis, and the Madison is considered to be of Kinderhookian and Osagean age, while the Brazer includes strata equivalent to the Meramecian and Chesterian (317, p. 1150). In some areas, however, separation is difficult, and these formations have been mapped together. Only the Brazer has been recognized near Malad, Idaho (315).

In southwestern Wyoming Rubey and Williams have distinguished an unnamed lithologic formation partly Mississippian and partly Pennsylvanian in age which may be equivalent to the Amsden.

Yellowstone National Park, Wyoming, Column 43.—The Mississippian section here is very similar to that in southwestern Montana. Strata overlying the Madison, however, generally have been referred to the lower part of the Quadrant, whose upper part is recognized to be of Pennsylvanian age. Thompson and Scott, however, exclude Mississippian beds from the Quadrant (266, p. 350). These strata are probably equivalent to the Amsden formation as recognized near by in Montana and may correspond to the Sacajowea elsewhere in Wyoming.

Northwest-Central Wyoming, Column 44.—The Amsden is a widely recognized lithologic formation whose upper and lower boundaries probably do not correspond from place to place. In some areas, it has been thought to be entirely Mississippian (18, p. 310) and in others entirely Pennsylvanian (45, p. 136; 163, p. 7); mostly it appears to transgress the systemic boundary. The name Sacajawea was proposed for beds included in the Amsden which were supposed to be of pre-Chesterian age (17, p. 653), but it has been used by some for all beds of supposed Mississippian age formerly included in the Amsden (265, p. 121). The fossils, reported from the Sacajawea, are not conclusive, and these strata may be of Chesterian age. The utility of this formation as a mappable unit has been questioned (164, p. 27), and many geologists continue to refer these beds to the Amsden formation because of lithologic similarity. Blackstone, Love, and Thomas recognize a widespread unconformity at the base of the Darwin sandstone which they consider the lowest member of the Amsden, and they refer the entire formation, not including the Sacajawea, to the Pennsylvanian. Obviously, agreement on the boundaries of the Amsden must be reached before an age assignment of this formation can be made. No Amsden is present near Casper unless it is included in either the Casper or Fountain formation.

Hartville uplift, Wyoming, Column 45.—The Guernsey formation of this area is approximately equivalent to the Madison limestone of the region to the west, although correlation of the upper boundaries is much in doubt, and to the Pahasapa and Englewood limestones of the Black Hills (56, p. 8). Its fossils need to be more carefully collected and studied.

Black Hills, South Dakota, Column 46.—The Englewood limestone is of later Kinderhookian age, as shown by the association of *Paraphorhynchus* and *Productus s. l.* Shale varying from dark gray to purplish constitutes the base of this formation at some outcrops and may correspond to black Kinderhookian shale in other regions. No sharp change in fauna occurs at the top of the formation, and the overlying Pahasapa limestone probably includes Kinderhookian beds in its basal part. The Pahasapa appears to continue to uppermost Osagean or Meramecian as evidenced by the presence of *Pentremites*. Considerable variation in thickness of this formation suggests that its upper part probably varies in age from place to place as the result of pre-Pennsylvanian erosion.

The Charles limestone, recognized in the subsurface of western South Dakota by Rothrock and others, may correspond to part of the upper Pahasapa, but more probably it is younger than any exposed strata.

Lithologic similarity of the Minnelusa and Amsden, as the latter is identified in some areas, suggests the correlation of these formations (5, p. 115; 121, p. 133). However, characteristic Pennsylvanian fossils have been collected from the base of the Minnelusa in the southern Black Hills (77, p. 620), and consequently this formation cannot be equivalent to the Mississippian Amsden.

Similar subsurface stratigraphic sections occur in neighboring parts of Wyoming and Montana.

Northwestern and Northern Colorado, Column 47.—All Mississippian strata in this region are referred to the Madison limestone (120, p. 45). Higher beds in the vicinity of Glenwood Springs, formerly considered probably to be equivalent to the Brazer (15, p. 538), are now known to be of early Pennsylvanian age (264, sheet 1).

Central and Southwestern Colorado, Column 48—Beds of Madison age in these parts of the State are referred to the Leadville limestone (120, p. 45). Fossils are generally scarce, but the *Spirifer centronatus* fauna has been found locally (119, p. 339). This formation was deposited upon an irregular surface and was unevenly eroded before burial beneath the Pennsylvanian; consequently both its upper and lower limits may vary considerably.

Part or all of the Ouray limestone, restricted to beds of Devonian age by Kirk (136, p. 239), are believed to be equivalent to the Percha shale of New Mexico by Stainbrook, who refers the latter formation to the lower Mississippian (252).

Front Range, Colorado, Column 49.—Mississippian strata in the Colorado Springs-Pueblo region known for many years as the Millsap limestone (15, p. 539) are now

referred to the Madison limestone by the United States Geological Survey, but Johnson and others prefer to term them Leadville (120, p. 43).

The Mississippian is reported to be generally absent in the Front Range north of Perry Park, and Mississippian fossils obtained in that area are believed to have come from boulders in clastic beds of Pennsylvanian age. Chert pebbles with Mississippian fossils occur commonly in Pennsylvanian conglomerates and also in Tertiary conglomerates at some localities suggesting that the Mississippian was once present throughout much of the Front Range area (15, p. 539).

New Mexico, Column 50.—Rocks of Mississippian age outcrop in the central and southwestern parts of the State. The name Caballero has recently been proposed for beds removed from the basal part of the Lake Valley formation because they bear a late Kinderhookian fauna. The restricted Lake Valley is of Osagean age and ranges from Fern Glen to lower Burlington as shown by its crinoids and is subdivided into three members (14, p. 25). One of these, the Alamagordo limestone, is characterized by conspicuous crinoidal bioherms (147, p. 2126).

The Kelly limestone of the Magdalena district (258, p. 14) has been considered equivalent to the Lake Valley, but Laudon believes that it is younger (upper Burlington or Keokuk) and overlies strata of typical Lake Valley age.

The Helms formation, present only in the southern part of the State, is of Meramecian and possibly Chesterian age, and Laudon reports that these two parts should be distinguished as separate formations. *Leiorhynchus carboniferum* has been collected from its lower part, which is believed to correspond approximately to the Ruddell shale (formerly Moorefield) of Arkansas. Laudon believes that the upper part is also of Moorefield age, but possibly it corresponds to the Fayetteville shale. These post-Osagean beds succeed older formations unconformably and locally overlap onto pre-Osagean strata.

The Percha shale generally has been referred to the Upper Devonian (14, p. 24), but its physical characters suggest that it may be the southwestern equivalent of the so-called Chattanooga shale of the continental interior. A recent study of its brachiopod fauna, which is reported to include *Paraphorhynchus* and numerous productids, has convinced Stainbrook that it should be referred to the basal Mississippian (252). This suggests that it may be of middle New Albany or early Kinderhookian age.

Several hundred feet of strata assigned to the Mississippian has been found in the subsurface of southeastern New Mexico (134, p. 21).

Hueco Mountains, Texas, Column 51.—The section here and in the Franklin Mountains is similar in many respects to that in New Mexico. The lower part of the Canutillo formation consists of very cherty limestone from which Devonian fossils have been obtained. The suggestion has been made that these strata may correspond to the unfossiliferous Caballos chert of the Marathon district (133a). The upper part of the Canutillo is dark shale probably equivalent to some part of the Percha shale of New Mexico.

The Helms formation includes all strata generally referred to the Mississippian. Two parts have been recognized. The lower has been identified with the Lake Valley

limestone (131, p. 909), but recent investigations suggest that no beds older than the Meramecian are present, and it is now considered to be of Moorefield age. The upper part is reported to carry Chesterian fossils (133a). Therefore this formation appears to be approximately equivalent to the Barnett shale of central Texas and the Caney shale of Oklahoma.

West-central Tamaulipas, Column 52.—A small isolated area of Mississippian rocks occurs near Peregrina, 7 mines northwest of Cuidad Victoria (192, p. 7). Fossils examined by Stuart Weller were reported to be of about Keokuk age. Girty noted that they resemble the typical Mississippi Valley fauna more than that which occurs in New Mexico (94).

Mississippian strata which may occur in the central highlands of Mexico have been involved in several post-Paleozoic orogenies, and have probably been so metamorphosed that their recognition will be very difficult.

SOUTHWESTERN INTERIOR

The Mississippian succession present at most places in this region, extending from the Ouachita Mountains far into Texas, is unique and exhibits few similarities with either the sections of the southern Rocky Mountains or the Ozark region. In general it is characterized by chert below and dark shale above.

Marathon basin, western Texas, Column 53.—Recent publications assign none of the strata in the Marathon region to the Mississippian System, but the age of the Caballos chert is admittedly doubtful, and somewhat unsatisfactory fossils have been discovered only in the upper part of the Tesnus formation. Doubtless the major part of the Mississippian is unrepresented here, but the remarkable similarity of the Caballos to the Arkansas novaculite (131, p. 1078) strongly suggests that these two peculiar formations contain strata of equivalent age. The Caballos is much the thinner, however, and consequently may not be equivalent to all three parts of the Arkansas novaculite, but which part or parts it does represent is not known.

In general, the Tesnus is similar to such other dominantly shale formations as the Caney in Oklahoma and the Stanley in Arkansas. These seem to indicate the former existence of an important geosynclinal trough in which a considerable thickness of clastic sediments accumulated. Poorly preserved plants from the upper third of the Tesnus were considered by White to be early Pennsylvanian (133, p. 61), but there is a distinct possibility that at least the Rough Creek member in the lower part of this formation should be assigned to the Mississippian System (132, p. 36).

Central Texas, Column 54.—The Mississippian section outcropping in central Texas is thin, but fossils indicate that several well-characterized zones are represented. The Chappel limestone, which is best developed as filling in ancient sink structures, contains both Late Kinderhookian and Osagean species and probably differs in age from place to place. Plummer recognized three lithologic members (209). Possibly some of the limestone, locally identified as Chappel, is equivalent to the lower part

of the Barnett as distinguished at other places (54). In subsurface the Chappel becomes more regular and considerably thicker and probably is equivalent to the Sycamore limestone of Oklahoma.

The Barnett shale is similar lithologically and faunally to the lower part of the Caney shale of Oklahoma. Generally, it has been correlated with the Chesterian (236, p. 91), but its relations to the Ruddell shale of Arkansas seem to be much closer. Cloud believes that no strata younger than Warsaw occur in outcrop and correlates most of the formation with the Keokuk, but Plummer assigned at least part of it to a considerably higher position in the section (208, p. 381). It is doubtful, however, that any strata of Chesterian age outcrop. This formation also thickens considerably in subsurface where younger beds may be present.

Southwest of Arbuckle Mountains, Oklahoma, Column 55.—Sections on opposite sides of the Arbuckles are similar in most respects. The Woodford chert represents both the middle and upper New Albany zones. The Sycamore limestone is a very sandy almost nonfossiliferous formation whose age has not been accurately determined. It is almost certainly equivalent to some part of the Chappel formation of Texas, and C. L. Cooper correlates it with the Chouteau. Northward in the subsurface, however, strata of "Mayes" character occur at the position of the Sycamore in an otherwise similar succession, and some, therefore, consider it to be of Osagean age.

The Caney shale was formerly considered to comprise all strata between the Woodford chert and Wapanucka limestone (Lower Pennsylvanian). After it was determined that both Mississippian and Pennsylvanian beds were included, use of the name Caney was restricted to the lower portion (25, p. 1316), and the name Springer was introduced for the upper or Pennsylvanian beds. As these two parts may be conformable and are not readily separable, the base of the Pennsylvanian System has not been determined accurately at many places (80, p. 1651). The lower part of the Caney contains the *Leiorhynchus carboniferum* fauna and, in the subsurface, passes into beds that have been termed "Mayes". The equivalent of the Fayetteville shale is probably present higher in the formation, and therefore most of the Caney is presumably of Chesterian age. The basal part, possibly separated from the Chesterian portion by an important but unrecognized hiatus, may be considerably older and appears to be equivalent to the Ruddell.

Northeast of Arbuckle Mountains, Oklahoma, Column 56.—In this area, the thin Welden limestone occupies the same stratigraphic position as the much thicker Sycamore limestone on the south flank of the Arbuckles (60, p. 381; 80, p. 1650). The Welden is fossiliferous, however, and contains trilobites of Upper Kinderhookian type, suggesting its correlation with Chouteau or higher beds. This conclusion is substantiated by the occurrence of a microfauna in underlying shale similar to faunas collected from shales underlying the Darty and Rockford limestones of Illinois and Indiana, respectively. At some places, particularly in the subsurface, limestone between the Welden and Caney has been termed "Mayes", but it is uncertain whether these beds should be recognized as a separate formation because they may be lenses

in, or a lateral gradation of, the basal portion of the sequence elsewhere identified as Caney (80, p. 1651). This limestone has been correlated with the Sycamore by some geologists who therefore believe that the Sycamore is younger than the Welden, but this conclusion appears to be quite uncertain.

The Woodford chert locally contains considerable black shale of Chattanooga type, and the two formations are known to be continuous in the subsurface although beds of later Kinderhookian age have not been identified and probably are not represented in the latter formation as it is developed in the Ozark region. The Woodford overlies older formations with conspicuous unconformity and in the subsurface locally overlaps onto the Arbuckle limestone. These relations are similar to those at the base of the so-called Chattanooga shale and its equivalents on the flanks of the Ozarks.

Ouachita Mountains, Arkansas, Column 57.—The section in this area is similar to that of the Marathon basin, and the occurrence of Mississippian beds has been questioned by many. The lower part of the Arkansas novaculite is Devonian, but the middle and upper portions appear to be equivalent to the Woodford chert (59, p. 311), and both Lower and Upper Kinderhookian beds are probably represented.

The thick Stanley and Jackfork formations and the underlying thinner Hot Springs sandstone have been assigned to the Pennsylvanian System in recent correlation tables (189), principally on the basis of White's opinion that the few plants discovered in these formations are Pennsylvanian. White, however, compared these specimens with floras from the basal part of the European Upper Carboniferous (310, p. 45) and from beds that are now believed to be of late Mississippian age. Consequently it is possible, if not probable, that the Stanley and Jackfork must be removed from the Pennsylvanian System and correlated with upper Mississippian formations known to occur in a few other parts of the United States.

MID-CONTINENT SUBSURFACE

COLUMNS 58-62

Insofar as known the subsurface development of Mississippian formations in Texas differs little except in thickness from the outcropping sections, and no separate stratigraphic columns seem necessary for the chart. Subsurface sections in Oklahoma would illustrate the important transition between the Arbuckle Mountains and the Ozarks, but correlations are uncertain, and the nomenclature unstandardized, and so their presentation might result in considerable confusion. The principal difficulties constitute a part of the "Mayes" problem that is discussed elsewhere.

The Kansas sections illustrate Lee's interpretations of variations in the Mississippian section (151). The formations shown have been recognized, of course, mainly by their lithologic similarity to outcropping sections. Strata presumably of Chesterian age occur in southern and western Kansas and extend into the neighboring parts of Oklahoma and Colorado. The Spergen, St. Louis, and Ste. Genevieve limestones are believed to be present, but because their separation is generally unsatisfactory the subsurface name Watchorn has been used for all of them.

Some of the most interesting beds in this region constitute the subsurface Cowley formation, the interpretation of which is closely connected with the "Mayes" problem. Lee believes that these beds are a distinct formation underlying the Warsaw, as locally recognized, unconformably overlying older strata, and locally completely overlapping the Boone equivalents. Other subsurface geologists disagree and contend that the Cowley grades laterally into the Boone. Laudon believes that beds termed Warsaw in the subsurface and outcropping sections in this and neighboring regions are miscorrelated and that the Cowley formation overlaps and locally cuts out the so-called Warsaw of southwestern Missouri.

Recognition of the Gilmore City limestone above the supposed Sedalia in this region is significant in connection with the classification and correlation of these formations which are not typically associated in any outcrop.

In Sedgwick County, Kansas, a bed of dolomite is present in the midst of the Chattanooga shale (274). Because it occurs beneath a sandy zone that has been correlated with the Misener sand it has been referred to the Devonian by some. Possibly, however, this sand is equivalent to the Bushberg, and the main part of the black shale here and in neighboring areas may be of late rather than middle New Albany age.

The Nebraska section differs from that of Kansas only by the presence of shale correlated with the Hannibal formation (216) whose deposition seems to have been largely restricted to the Forest City basin area.

OZARK REGION

The Mississippian formations of the southern Ozark region are closely related to those in the type area, but complications resulting from various changes in lithologic facies and faunas make the precise correlation of several formations more or less uncertain.

Northeastern Oklahoma, Column 63.—The cherty Mississippian limestones of the Ozark and neighboring regions have long been known as the Boone formation (88). From time to time, however, various parts of this section have been split off, mainly on lithologic grounds, and named as separate formations. Thus today the Boone as so restricted is generally considered to consist of only Burlington and Keokuk equivalents, but usage is not yet consistent. Opinions also have differed rather widely concerning the age of the beds which constitute the restricted Boone. For example Cline (53, p. 1148) and Laudon (146, p. 325) have not agreed regarding distribution of Burlington and Keokuk strata in northeastern Oklahoma and southwestern Missouri.

The "Mayes" formation has been a problem to geologists for many years. It was originally defined as including all strata between the Boone chert and Fayetteville shale and was assigned to the Chesterian Series. It is now known to consist of two parts; the lower is probably equivalent to the recently restricted Moorefield formation (96), and the upper is a limestone of Chesterian age at the base of the Fayetteville, for which the name Grand River has been used (23). Depending upon whether an

individual was more familiar with one part or the other, the name "Mayes" was used for beds of early Meramecian or of early Chesterian age.

The "Mayes" formation is not recognized by the Oklahoma Geological Survey, and it is now little used in connection with surface studies, but this name is still part of the vocabulary of many subsurface geologists. As the outcropping formations of northeastern Oklahoma are traced westward and southwestward in well records, the cherty light-colored Boone succession is replaced by dark limestone and shale that is commonly known as "Mayes". Cram has contrasted the two explanations advanced to account for this change either by the unconformable overlap of the Boone by younger beds or the lateral transition of one type of sediment into another in the direction of a geosynclinal trough (65, p. 561). Subsurface petroleum geologists almost universally consider the "Mayes" to be a facies alteration of the Boone, but Lee (151, p. 66), Laudon, Moore, and others are equally convinced that these strata replace the Boone by unconformity and overlap.

The Chattanooga shale, or Woodford chert, is locally absent in the subsurface, particularly in Osage County (148). The Misner sand of the subsurface is generally believed to be equivalent to the Sylamore and locally overlaps onto the Middle Ordovician.

Southwestern Missouri, Column 64.—The occurrence of strata of late Kinderhookian age and the reported presence of the Warsaw, Spergen, and St. Louis limestones seem to make the southwestern Mi- ... section one of the most complete in the Ozark region. The Compton limestone and Northview shale or sandstone appear to be of Chouteau and Sedalia age (124), and greenish shale that separates the Chattanooga from Mississippian limestone, known at various places in the southern Ozarks and in the subsurface of Oklahoma, may be an attenuated representation of the Northview.

Uncertainty regarding the identification of beds that make up the principal part of the Boone chert in southwestern Missouri was mentioned in the last section. According to Laudon the Reeds Spring limestone is easily recognizable by its lithologic characters throughout the Tri-State district, and the dark color of these beds in Oklahoma may be one reason for the conclusion of Brant and others that the subsurface "Mayes" is a lateral transition from the typical Osage of this region. The Grand Falls chert has been stated by Cline to be a local development in the upper part of the Reeds Spring (53, p. 1142).

The Pierson limestone, distinguished near Springfield (not indicated in the chart), has not received general recognition, but Kaiser states that it is a lithologic variant of the St. Joe (124) which occurs throughout much of southwestern Missouri, northeastern Oklahoma, and northwestern Arkansas.

Kaiser has recognized the same faunal zones in the Burlington that were described by Laudon in northeastern Missouri and Iowa (145). As traced southwestward, successive zones wedge out so that younger portions of this formation overlap onto the Reeds Spring, and in the southwest corner of Missouri no Burlington occurs beneath the Keokuk (124).

The presence of Warsaw and Spergen limestones in the Joplin district is recognized

by the Missouri Geological Survey, and these formations have been mentioned by Gordon (96, p. 1629), but the latter formation has never been described in this region. Laudon states that no Warsaw occurs in the Tri-State district and that beds carrying *Productus* (*Marginirugus*) *magnus*, considered by some to be indicative of the Warsaw, are upper Keokuk.

The Short Creek oölite (not shown on chart) has been considered a member in the lower part of the Warsaw in this region, but several oölitic zones, one of which may be as old as St. Joe, appear to have been confused locally.

St. Louis limestone, recognized on the basis of *Lithostrotionella castelnaui*, or a similar coral, is present in southwestern Missouri (51). Somewhat similar corals occur in northeastern Oklahoma, but specimens submitted to J. M. Weller are an undescribed species probably referable to this genus and may be indicative of strata considerably younger than St. Louis. This latter occurrence seems to be the easternmost extent of a coral fauna known at several places in the Rocky Mountains and contiguous regions of the west which has been a confusing element in the paleontological correlations of certain western Mississippian formations with the type section.

The Hindsville, Batesville, and Fayetteville formations have been recognized in a limited area in southwestern Missouri. Undifferentiated beds of similar age, mostly preserved in sink structures of the Joplin district, are known as the Carterville formation.

The Mississippian limestone of the Joplin district has been subdivided into a number of lettered zones (188) that have been used considerably by field geologists, but few references to them occur in publications.

Northwestern Arkansas, Column 65.—The Mississippian section in this area differs from that in the Batesville district mainly in the relations of the various Chesterian formations and members. Several unconformities are possibly present, and some of these units may disappear as the result of erosion and overlap, but in general field observations have not been sufficiently detailed to demonstrate that none has resulted from lateral gradation.

The St. Joe limestone is remarkably similar to the Fern Glen, both lithologically and faunally. It is also remarkable because of crinoidal bioherms, particularly in Oklahoma, and the occurrence of distinctive biohermal and interbiohermal facies (146, p. 326). Laudon reports that both the Reeds Spring and Pierson limestones are recognizable in this area.

The Sylamore sandstone below the Chattanooga shale occurs at the same stratigraphic position as the Hardin sandstone of Tennessee, the Misner subsurface sand of Oklahoma, and a sand recognized in the subsurface of Illinois. This widespread sandy zone at different places may be of different ages ranging from early to middle New Albany. Gordon reports the presence of two sandstones in central northern Arkansas. The former correlation of the Sylamore and Bushberg sandstones is now generally recognized to be untenable.

Batesville district, Arkansas, Column 66.—The Mississippian succession has been studied in the Batesville district more intensively than in any other part of Arkansas.

Several of the formations have been variously correlated with the standard section, and some correlations are not yet satisfactorily established. All strata above the Batesville sandstone are undoubtedly of Chesterian age, but the section is quite different from that developed in southern Illinois. C. L. Cooper states that an ostracode fauna from the base of the Fayetteville appears to be of Golconda age and that Pitkin ostracodes most closely resemble those of the Clore and Kinkaid. Also Easton has reported similarities in the corals of the Pitkin and Kinkaid (83, p. 383).

The Batesville sandstone appears to be pre-Golconda, but this formation is hardly thick enough to be equivalent to all of the lower Chesterian plus the Cypress. Beds of earliest Chesterian age may be absent although it is not impossible that the Ruddell shale and Moorefield formation should be assigned to this part of the section.

The Moorefield shale was originally considered to include all beds between the Boone chert and the Batesville sandstone. Later the Spring Creek limestone was described as a member at the base of the Moorefield, and this member was subsequently shown to be equivalent to beds in the upper part of the Boone as locally recognized. Recently Gordon has restricted the application of the name Moorefield to the Spring Creek member and proposed the new name Ruddell for the overlying shale (96). This is confusing from a purely stratigraphic standpoint because the Moorefield, so long regarded as a shale, becomes a limestone, yet paleontologically this procedure was advisable because the well-known Moorefield fauna occurs principally in these limestone beds.

The Moorefield fauna is noted mainly for its goniatites and *Leiorhynchus carboniferum*. The latter species also occurs in the Floyd shale of Alabama, the Fayetteville shale of Arkansas, the lower "Mayes" of northeastern Oklahoma, the lower part of the Caney shale of southern Oklahoma, the Barnett shale of Texas, the Big Snowy group of Montana, the Helms formation of New Mexico, the White Pine shale of Nevada, and the Calico Bluff formation of Alaska. Associated species in the Big Snowy group and Fayetteville shale are clearly of Chesterian age, but elsewhere other fossils give less aid in dating the *Leiorhynchus* fauna. The reported presence of *Productus* (*Diaphragmus*) *elegans* and some other species (92, p. 22) has suggested a possible Chesterian age for the Moorefield fauna, but Gordon states that these are Fayetteville specimens which became mixed with a Moorefield collection (96, p. 1630). *Leiorhynchus* is associated in the lower "Mayes" with *Griffithides pustulosus* (249, table), a trilobite that strongly suggests upper Osageaon or lower Meramecian rather than younger zones.

The Ruddell and Fayetteville shales are similar lithologically and have been confused in the past. Brant believes that they are still confused and states that well records in northern Arkansas show no shale at the proper position of the Ruddell. Gordon disagrees.

Productus (*Marginirugus*) *magnus* is present in the upper part of the Boone near Batesville, and these beds have been referred to the upper Keokuk or lower Warsaw. The St. Joe limestone is less persistent here than to the west, and locally the basal Boone strata are of Reeds Spring type.

An unnamed greenish shale at the base of the Boone near Batesville (97) is believed by Gordon to be of Hannibal age.

UPPER MISSISSIPPI AND LOWER OHIO VALLEYS:

THE TYPE AREA

The columns for this area form the nucleus of the chart, and all other columns are correlated directly or indirectly with them. The type localities of all formations in the standard stratigraphic section occur in this area, and the correlations of most of the formations indicated here are reasonably well established. Except for minor details the stratigraphic nomenclature employed in the type area has been static for 25 years.

Central Missouri, Column 67.—The upper part of the original Chouteau limestone of the Kinderhookian group was separated under the name Sedalia limestone and correlated with the Fern Glen formation of the Osagean group by Moore (183, p. 150). Branson has not recognized the Sedalia nor the restriction of the Chouteau but correlates the latter with the Fern Glen (22, p. 198). Clark reports that recent investigations in central Missouri indicate that the Sedalia is very closely related to the Chouteau and is part of the Kinderhookian Series. Lee has identified beds which he correlates with the Sedalia between the Chouteau and Gilmore City limestones in the subsurface of Kansas (151).

Subsurface records extending northwestward from this area show the presence of limestone correlated with the Warsaw, St. Louis, and Ste. Genevieve and also black shale of Chattanooga type and strata that are possibly of Chesterian age (173, p. 29).

North-central Iowa, Column 68.—This is the only portion of the type region in which beds constituting the upper part of the Kinderhookian Series occur in outcrop. The Gilmore City (formerly Alden) limestone is referred to the Kinderhookian by Laudon (144, p. 7) and the Iowa Geological Survey, although its oölitic character caused others to consider it as young as Salem (185, p. 245). In this area the Burlington, Keokuk, Spergen, and Warsaw formations have wedged out, and the St. Louis overlaps onto the Kinderhookian (144, p. 15). Correlations of the various members of the Hampton formation have not been established, but they may be equivalent to the Chouteau and Sedalia limestones of Missouri.

Southeastern Iowa, Column 69.—This is one of the classic Mississippian areas of the United States and includes the type localities of the Burlington and Keokuk limestones, whereas the type locality of the Warsaw lies just east of the Mississippi River in Illinois. The Spergen (or Salem) limestone of this area does not resemble the typical Salem of Indiana, and J. M. Weller has stated that the restriction of the Warsaw formation, which resulted from recognition of the Spergen, was ill-advised (286). Here also is one of the best-known upper Kinderhookian sections.

The Maple Mill (formerly termed Sweetland Creek) includes all of the Kinderhookian shale in southeastern Iowa (143, p. 355), but only the upper part is exposed at the type locality. A limestone, tentatively correlated with the Louisiana by Iowa geologists, has been encountered in several wells in the midst of this shale (201,

p. 683). At Sweetland Creek only the lower beds are present between Devonian and Pennsylvanian strata. *Spathiocaris emersoni* has been reported here (273, p. 70), and the conodonts are similar to those in the Grassy Creek shale of Missouri (179). These beds are probably of middle New Albany age. Shale equivalent to the Maple Mill, as this formation is defined in Iowa, has been penetrated in the wells of western Illinois, and it has been termed Sweetland Creek shale in many publications of the Illinois State Geological Survey (289, p. 783).

The Burlington limestone has been zoned in this area and in the neighboring part of Missouri by Laudon on the basis of crinoids (145, p. 1161). He has reported that upper zones overlap lower ones in the direction of central Iowa (145, p. 1167) where this formation and others disappear and the St. Louis limestone directly overlies the Kinderhookian (173, p. 231).

Illinois west of Illinois River, Column 70.—This area is continuous with Southeastern Iowa, and the stratigraphic section is similar except that the lower Kinderhookian is better differentiated and the upper Kinderhookian is somewhat differently classified. All but the uppermost Kinderhookian formations are represented in northeastern Missouri, and several of them have their type localities there. The upper part of the Hannibal shale and Chouteau limestone appear to grade into one another, and where one is thick the other is thin. The Prospect Hill sandstone, McCraney limestone, and English River sandstone are thin and are probably best considered as members of the Hannibal formation. They are closely related to the section shown in the last column and do not occur in Missouri or at other places where the Chouteau is developed. Their relations to the Chouteau are not definitely known but are probably approximately as indicated. The Hamburg beds contain a peculiar fauna similar to that of the Glen Park limestone (294, p. 464). Both are believed to be Devonian by Branson (21, p. 179), but they are clearly a part of the Upper Kinderhookian succession, and the Hamburg is best considered a member of the Hannibal. Subsurface studies in Illinois by Gillette and Workman suggest the presence of a widespread unconformity at the base of this formation as so constituted.

The Louisiana limestone is a lenticular formation and grades downward into the Saverton shale. Lateral gradation may also occur but has not been established. The Grassy Creek and Saverton shales differ notably in color and texture but appear to intergrade. Branson and Mehl recognize only a single formation (19, p. 174). J. M. Weller has questioned the validity of the name Grassy Creek because the black shales on Grassy Creek are part of the Maquoketa (Upper Ordovician) formation (287). Where the Louisiana limestone and Hamburg beds are absent, separation of the Hannibal and Saverton shales is very difficult, and where Kinderhookian shale overlies the Maquoketa (140, Pls. 15, 16) distinction in the subsurface is not clear.

In part of this area the St. Louis limestone is unusually thick and locally includes oölite in the upper part. Possibly some of the Ste. Genevieve is represented here, but the latter formation has not been separately distinguished (140, p. 42). Gypsum and anhydrite have been identified in well cuttings from the St. Louis in parts of western Illinois (204, p. 231) and southern Iowa (201, p. 90). This suggests the

possible correlation of some of the evaporite beds of the Marshall formation in Michigan with part of the St. Louis.

Monroe County, Illinois, Column 71.—The Upper Mississippian Chesterian Series was first subdivided in this area, and half of the formations of the standard Chesterian section have their type localities in Monroe or neighboring counties (297, p. 120). An important unconformity occurs at the base of the Chesterian Series which resulted from the uplift and erosion of underlying strata, and locally the Chesterian overlaps the Ste. Genevieve and directly succeeds the St. Louis limestone (303, p. 10). J. M. Weller has suggested that the Aux Vases sandstone might better be considered a basal member of the Renault formation occupying channels cut in underlying beds (303, p. 10). If this interpretation were followed it would not be necessary to indicate a hiatus between the Meramecian and Chesterian series in some other areas. A widespread unconformity occurs at this contact, but the faunas of the upper Meramecian and lower Chesterian are similar in many respects, and no long time break is indicated.

In this area the *Productus* (*Marginirugus*) *magnus* zone has been included in the lower part of the Warsaw formation (302, p. 197), and there may be a discrepancy in the Meramecian-Osagean boundary as recognized to the north and east as contrasted with the region to the southwest.

The Burlington and Keokuk limestones have not been satisfactorily separated here. Fossils show that equivalents of both are present, but it is convenient to consider them a single formation.

This is one of the very few areas in the type region where the Kinderhookian Series is known to be entirely unrepresented. The absence of these beds here reflects the influence of the Ozark dome which was an active positive element throughout much of Paleozoic time.

Southeastern Missouri, Column 72.—The Mississippian section in Ste. Genevieve and Perry counties is very similar to that in the last column except that some of the upper Chesterian formations have been removed by erosion, and thin and intermittent strata of Kinderhookian age are present. An unconformity separates the St. Louis and Ste. Genevieve limestones (302, p. 214) although these formations appear to be conformable and transitional throughout most of their extent elsewhere. This unconformity reflects the influence of the positive Ozark dome which also contributed the sand that is a conspicuous constituent of the Renault formation and Ste. Genevieve limestone in this general region. The Spergen limestone as locally recognized contains *Lithostrotionella* in its upper part and (302, p. 213) probably includes beds younger than any of the Salem of Indiana.

Union County, Illinois, Column 73.—The standard succession of Chesterian formations is fairly well represented in this area, but the section thins westward toward the Ozarks, several of the sandstones seem to lens out in that direction, and the lower Chesterian has not been subdivided (290, p. 22). This is the only area in which the Hoffner member of the Ste. Genevieve is known to outcrop. These beds consist

mainly of shale and sandstone and closely resemble the Chesterian lithologically but contain such characteristic Ste. Genevieve fossils as *Platycrinites huntsvillae* and *Pugnoides ottumwa*. If the Aux Vases sandstone were considered a member of the Renault, no hiatus would be indicated here.

The Osagean is practically nonfossiliferous limestone, and although the Burlington and Keokuk are probably represented it is not known that strata of Fern Glen age are present.

The Springville shale is nonfossiliferous and has been generally classed as Kinderhookian, although it might be correlated with the New Providence of Indiana. Limestone that was formerly included in the basal Springville is here distinguished as the Darty limestone, named from a tributary of Caney Creek west of Jonesboro. It is probably equivalent to the Rockford limestone of Indiana, as a thin underlying shale contains the same microfauna that is known from beneath that formation and from below the Welden limestone in Oklahoma.

Hardin County, Illinois, and western Kentucky, Column 74.—This is the area of typical development of the Chesterian Series. The correlations shown are those generally accepted although there are some uncertainties, and the accompanying supplementary table indicates the correlations favored by some subsurface geologists of wide experience (71). Disagreements center largely upon the correct identification of the Cypress sandstone in Indiana (type locality in southern Illinois) and the correlation of the Bethel sandstone with the Yankeetown chert. The name Downeys Bluff limestone, proposed by Tippie, is derived from a hill on the north bank of the Ohio River just below Rosiclare, Illinois. It is now generally recognized that strata identified as Aux Vases in the subsurface of Illinois probably represent different zones at different places and may include beds of true Aux Vases, Hoffner, and Rosiclare ages. The Bethel sandstone was correlated with the Aux Vases by Ulrich (272, p. 9), but this correlation is not accepted by any geologists working in this area (Fig. 4).

A sandy zone within the Fedonia member of the Ste. Genevieve has been designated the Spar Mountain sandstone. Some believe unconformities occur at the base of the Rosiclare and at the top of the Spar Mountain members (268), but J. M. Weller and others (150) conclude that the evidence has been misinterpreted.

Osagean beds consist of very siliceous limestones of the Fort Payne type, contain very few fossils, and outcrops are generally much leached. No shale of New Providence type is present here, and it is uncertain whether the Osagean succession continues downward to include strata of New Providence or Fern Glen age.

Thin shale below the Osage chert and above the New Albany black shale (termed Chattanooga in the past) contains a few poorly preserved fossils suggesting that it is equivalent to the Rockford. The three conodont zones of the New Albany shale have not been recognized here, but the great thickness of this formation indicates that probably all parts of the typical New Albany are represented.

West-Central Kentucky, Column 75.—Several of the standard Chesterian formations become unrecognizable in parts of this area (284), and this section resembles in many

respects the Chesterian as developed on the east flank of the Cincinnati arch. The name Gasper, applied so widely by Butts to the east and south, probably has its type locality here, but Sutton and Weller have stated that this name has been used so indiscriminately that it has little significance (260, p. 439).

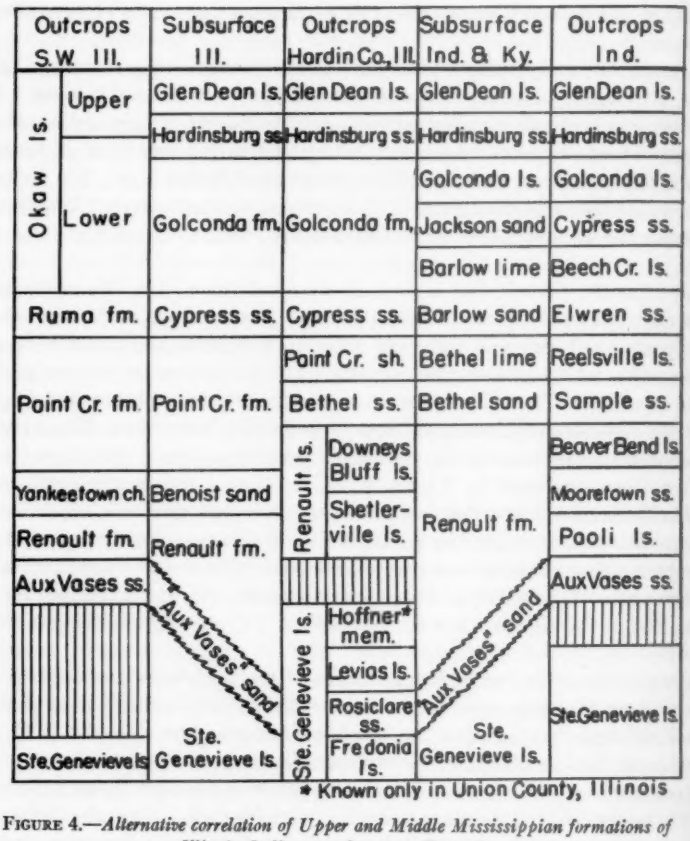

FIGURE 4.—*Alternative correlation of Upper and Middle Mississippian formations of Illinois, Indiana, and western Kentucky*

Strata equivalent to the Salem limestone are undoubtedly present, but this formation cannot be recognized faunally or lithologically.

Subdivision of the Osagean group is largely based on lithologic differences (254), and the succession of formations recognized here is a modification of the Indiana section (253). The New Providence shale possesses a fauna of pre-Keokuk age and generally has been correlated with the lower Burlington (251, p. 207). Some elements of its fauna are similar to species in the Fern Glen (296, p. 325), and Kirk be-

lieves that at least some part of the Fern Glen is represented in the typical lower Burlington. Laudon does not agree. Girty pointed out that practically all fossils from the New Providence have been obtained from its middle or upper parts and suggested that the lower part of the formation may be of Kinderhookian age (29, p. 147). The apparent absence of upper Burlington faunas in the region east of the Mississippi Valley presents a problem demanding careful investigation.

A zone containing glauconite and phosphatic concretions just above the black shale, reported in western Kentucky as well as elsewhere (44), is suggestive of the Maury shale of Tennessee and the unnamed shale of possible Rockford age in southern Illinois. A thin bed of this type is much more generally present than has been recognized to date. Subdivision of the New Albany shale comparable to that of the Indiana section has been made by Campbell (44).

Southwestern Indiana, Column 76.—Many subdivisions of the Chesterian section as worked out in Indiana originally received local names although a few names were introduced from the neighboring part of Kentucky (69, p. 514). Now, however, names of wider application are used for most of the formations. Uncertainty regarding the identification of the Cypress sandstone has been mentioned in a previous section. The Sample sandstone was named by Butts from a locality in Breckenridge County, Kentucky, and was considered by him to be younger than the Bethel (30, p. 37). The correlation of the Sample and Bethel sandstones is now generally accepted, and the former name has been largely abandoned elsewhere. The Aux Vases sandstone and the Rosiclare sandstone members of the Ste. Genevieve have been recognized locally in Indiana (168, p. 323).

The Salem limestone of Indiana is a well-marked and easily identified formation. The name Spergen, adopted by the United States Geological Survey for this same unit and used in several other States, is more recent, nongeographic, and less desirable. The Salem and Harrodsburg limestones together are approximately equivalent to the Warsaw formation as formerly recognized in the Mississippi Valley. The attempt to distinguish and separate a Salem or Spergen formation in areas outside of Indiana has resulted in the restriction of the Warsaw formation in these areas; elsewhere the name Warsaw has been used for all strata between the St. Louis limestone and beds of Keokuk age and undoubtedly includes Salem equivalents. Butts suggested that the Salem be considered a member of the Warsaw (32, p. 119), and J. M. Weller favored a return to the original definition of the Warsaw and the recognition of beds of Salem age outside of Indiana as a member where convenient or desirable (286). The absence of typical Salem beds has resulted in the local recognition of a supposed unconformity below the St. Louis limestone (30, p. 35) where none actually occurs.

The New Albany shale is typically developed in this area, and here the three conodont zones previously discussed have been distinguished (114). This is also the principal section that has been subdivided into formations by Campbell (44). Several of the latter are very thin. Malott and Esarey doubt their continuity for even short distances and believe that they are of little significance.

EASTERN INTERIOR BASIN—SUBSURFACE

COLUMNS 77, 78

The subsurface stratigraphic section of the Eastern Interior basin of Illinois, Indiana, and western Kentucky consists mostly of the same formations that are recognized in outcrop. Oil production has been obtained from many different zones, and each of the Chesterian sandstones is productive at one place or another. Most of these are known by their regular geologic names, but a few of the more important ones have received subsurface names that are more or less widely employed.

Subsurface studies suggest that some of the correlations between the outcrops of Illinois and those of Indiana and western Kentucky are in doubt (71) and alternative correlations are shown in Figure 4.

Detailed subsurface studies and correlations by electric logs strongly suggest that strata identified as Aux Vases in the Wabash Valley fields occur at the position of the Rosiclare member of the Ste. Genevieve. If this conclusion is correct this part of the upper Ste. Genevieve must grade into strata in the basin different from anything certainly identified in outcrop. Perhaps the Hoffner member of the outcropping section in Union County, Illinois, is a similar development of the Rosiclare zone misplaced stratigraphically because an underlying sandstone, comparable to the Spar Mountain member of Hardin County, Illinois, has been wrongly identified as Rosiclare. It is also possible that the true Aux Vases of the Wabash Valley area has been misidentified as the Benoist subsurface sand.

The McClosky "sand" is a name applied to any porous zone in the Ste. Genevieve limestone. It may occur at the top of this formation or may be as much as 100 feet below the Rosiclare sandstone (204, p. 229) but is most commonly in the upper part of the Fredonia member.

The nomenclature applied to subsurface sands in Indiana is generally similar to that of Kentucky. A considerable number of other names has been used very locally in the older oil pools of all three States (289, p. 853).

MICHIGAN BASIN

Thick glacial deposits conceal the bedrock throughout most parts of the Michigan basin, and outcrops of Mississippian strata are not abundant. Consequently much of the available information concerning the stratigraphic succession, lithologic character, and thickness of the various formations has been derived from the records of deep wells. Although now entirely isolated from other areas of Mississippian rocks, the Mississippian formations of Michigan must formerly have been continuous with strata of similar age in neighboring States. The occurrence of gypsum and anhydrite in the formations in Michigan, however, suggests that the marine connections of this basin were probably considerably restricted at times.

Milwaukee, Wisconsin, Column 79.—The "Kenwood" shale (name preoccupied) does not outcrop but is known from excavations for an intake tunnel of the Milwaukee city water works (214, p. 262). It is predominantly black and contains conodonts and a few other fossils which, according to C. L. Cooper, indicate its middle

New Albany age. Similar shale has been observed in joints enlarged by solution in the Niagaran dolomite near Chicago (84; 293).

Small areas of Mississippian limestone of Osagean age may be preserved beneath the glacial drift of southeastern Wisconsin, inasmuch as chert pebbles with Osagean fossils have been found in the glacial deposits of northeastern Illinois (289, p. 806).

Western Michigan, Column 80.—Knowledge of the paleontology of the Mississippian formations of Michigan is very incomplete, and consequently correlations are uncertain. The section is, in a general way, similar to that in Ohio and consists of dominantly clastic sediments enclosed between black shale below and limestone with Meramecian fossils above. *Lithostrotionella castelnaui* occurs in the Bayport limestone and relates this formation to the St. Louis. Ehlers suggests that it may also include beds of Ste. Genevieve age. Goniatites in the sandstone of the Lower Marshall are similar to those in the Rockford fauna of Indiana. Intervening strata have yielded few fossils.

The term Marshall group has been used rarely in recent years, but the common recognition of a Lower Marshall sandstone implies the existence of an Upper Marshall. The latter is the Napoleon sandstone which has been variously included in or excluded from the Marshall group by different persons.

The Marshall group and the thick Coldwater shale have generally been referred to the Kinderhookian on the basis of the Marshall goniatites (243, p. 13). The Rockford specimens, however, were collected loose in the bed of White River (64, p. 45) and possibly came from strata immediately overlying the Rockford limestone which, according to C. L. Cooper, bears a microfauna quite different from that in and beneath that limestone. Therefore these goniatites may be of early Osagean rather than Kinderhookian age. This interpretation would accord better with the thicknesses of overlying and underlying strata that must be divided between the Upper Kinderhookian and the Osagean in Michigan.

The Ellsworth shale has been described as a formation whose deposition was limited by a barrier (100, p. 714), but more probably it grades laterally into the upper part of the Antrim shale and overlying formations. The Antrim generally has been assigned to the Devonian (62), but its upper part probably corresponds to the so-called "Kenwood" shale of Wisconsin and Cleveland shale of Ohio which are of middle New Albany age.

Eastern Michigan, Column 81.—The Bedford, Berea, and Sunbury formations do not outcrop (194, p. 52). Their correlation, based upon lithologic character and stratigraphic succession, with similarly named formations in Ohio has not been proved although it appears likely. The Antrim shale undoubtedly contains beds of Devonian age, but the upper part may include Mississippian strata, as was believed by Ulrich (194, p. 48).

EAST SIDE OF CINCINNATI ARCH

Mississippian rocks outcrop continuously for a distance of 650 miles on the east flank of the Cincinnati arch from Lake Erie to northeastern Mississippi. Little

intensive stratigraphic work has been done in much of this region, and many details of correlation are more or less uncertain. Also the use of a considerable variety of stratigraphic names, some locally derived but many imported from other regions, is a source of possible confusion.

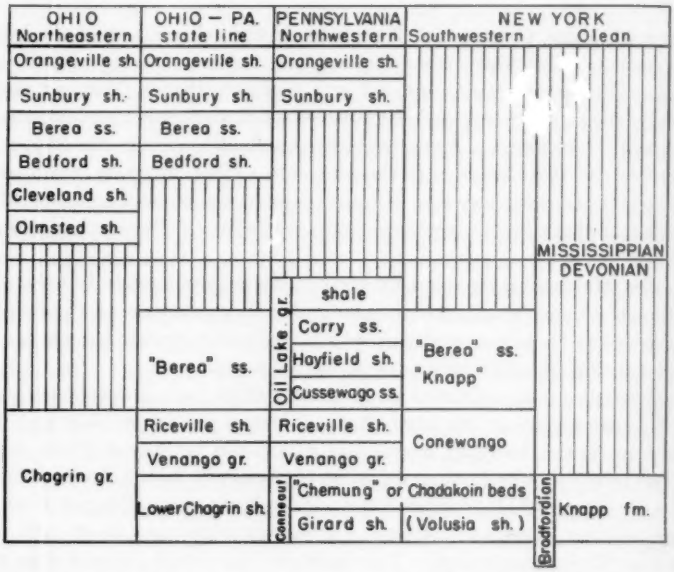

FIGURE 5.—*Correlation of Lower Mississippian and Upper Devonian formations of Ohio-Pennsylvania-New York region*
After Chadwick

Northwestern Pennsylvania, Column 82.—A great variety of names has been given to the upper Devonian and lower Mississippian stratigraphic subdivisions of this area, and they have been variously combined into formations or groups. One of the most elaborate classifications is that of Caster (46), but at present there appears to be little agreement regarding either the details of the stratigraphic succession or the correlation of the named units. The situation here is complicated because of marked lateral facies variation. Although a satisfactory solution to these problems may not have been reached, investigations have resulted in a better understanding of the problems here than in other parts of the northern Appalachian district where similar conditions probably prevail.

So many problems of correlation are evident here and in the neighboring parts of Ohio and New York that no brief discussion can present them adequately. Equivalence of the Chagrin shale of Ohio and part of the uppermost Devonian of Pennsylvania is generally agreed upon, but controversy exists regarding the relation of this formation to the overlying Cleveland shale. Those who believe that this contact is conformable and gradational consider overlying strata in Pennsylvania to be Mis-

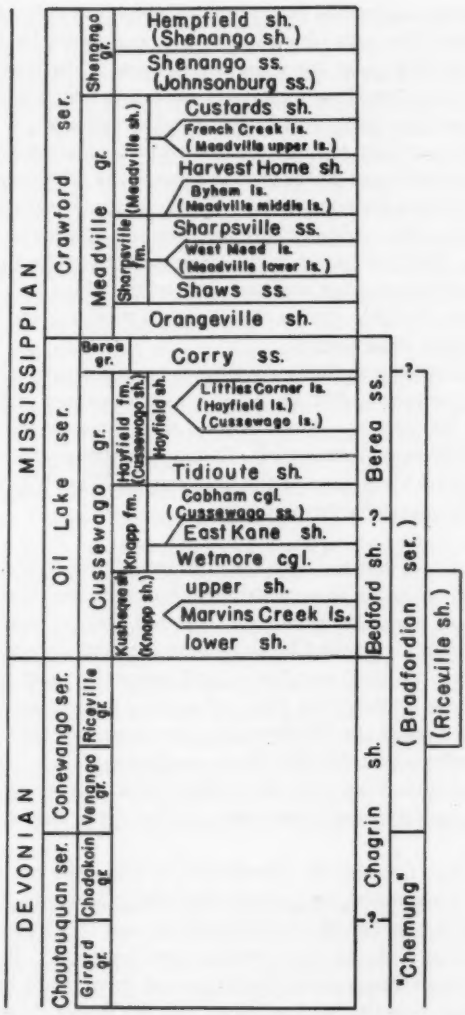

FIGURE 6.—*Classification and correlation of Mississippian rocks in northwestern Pennsylvania*
After Caster (46)

sissippian. Those who believe that this contact is unconformable conclude that these same beds in Pennsylvania are Devonian and that they are cut out by unconformity westward in Ohio. Moreover the correlation of these strata from place to place has been considerably influenced by conclusions regarding their facies variations. (*Compare* Figures 5 and 6.)

The stratigraphic succession shown in the main chart is that of Sherrill (76, p. 7).

The Corry sandstone is generally recognized to be equivalent to part, at least, of the Berea sandstone of Ohio with which it has been connected by subsurface studies, and furnishes a starting point for other correlations. The underlying Cussewago group, to part of which the Knapp formation or conglomerate of New York is probably equivalent, has been assigned to either the Devonian (47, p. 333) or Mississippian. These beds are stated to carry the first fauna of Mississippian type (46, p. 41; 142, p. 12), and present usage favors placing them in the Mississippian System.

Study of a fauna from the upper part of the Shenango formation led Busch to conclude that this formation could not be older than the Spergen or Salem of the type area (27, p. 154). This correlation, however, appears to be open to serious question. The faunal evidence is somewhat confused, and several of the listed species may have been misidentified. In Ohio similar clastic strata overlying the Cuyahoga are not known to be younger than Keokuk.

The youngest Mississippian beds of this area consist largely of shale and include red beds. They are termed Patton, a name used elsewhere in Pennsylvania for a red shaly zone in the Pocono. There is little or no evidence that these beds are of equivalent age at different places, and the Patton of northwestern Pennsylvania might as readily be correlated with part of the Maccrady of West Virginia or even part of the Mauch Chunk of eastern Pennsylvania.

Cleveland, Ohio, Column 83.—This is the type area of the Cuyahoga group or formation that has been variously interpreted as including or excluding the Bedford and Sunbury shales and Berea sandstone and that has been variously subdivided into formations or members. In the Cleveland area the Sunbury shale is very thin and has been considered the basal member of the Orangeville shale (70, p. 49). Fossils of the Cuyahoga give no indication that any strata younger than the Kinderhookian are present. The base of the Mississippian has commonly been drawn at a locally conspicuous unconformity below the Berea sandstone (213, p. 511), but the occurrence of *Spathiocaris williamsi* in the typical black Cleveland shale appears to demonstrate the equivalence of these beds with the upper New Albany.

South-central Ohio, Column 84.—Southward in Ohio the pre-Pennsylvanian unconformity is less pronounced, and younger Mississippian strata appear. Few fossils have been recorded from the Maxville limestone, and this formation has generally been correlated either with the Ste. Genevieve or Chesterian. Its position is similar to that of the Bayport limestone in Michigan, and there might be some basis for its possible correlation with the St. Louis also. J. M. Weller, however, believes that Maxville trilobites are indicative of Ste. Genevieve age.

In this area the Logan formation overlies the Cuyahoga, and together they and the underlying Sunbury, Berea, and Bedford consitute the Waverly group. This group consists largely of clastic materials and resembles the Borden group of Indiana in general lithologic composition and in its stratigraphic position between a thick black shale and a middle Mississippian limestone. The two principal formations of the Waverly group have been variously subdivided into members and are of particular interest because of the facies variations that were described by Hyde (116; 117,

p. 152). Although certain parts of the Cuyahoga and Logan formations are abundantly fossiliferous, the fossils of these beds have remained practically unstudied since the time of Winchell and Herrick. There are no lists of recently determined species. Herrick believed that the Cuyahoga is Kinderhookian in age and that the Logan represents the Keokuk (108, p. 512). Published paleontological evidence appears to be in harmony with this view, and at present no Burlington faunas are recognized in Ohio. These conclusions, however, are open to question because of uncertain identification of genera and species and because of the great lithologic differences between the Waverly group and the Osagean of the Mississippi Valley. This lack of lithologic uniformity between the two areas is almost certainly reflected by differences in the faunas. Finally, no important break in sedimentation or stratigraphic hiatus is known within the Waverly group, and consequently beds of Burlington age may be represented even though they have not been recognized.

Because of marked lateral variation, correlation of the more or less local members of the Waverly formations is somewhat doubtful. This is particularly true in the area south of Vinton County. In Hyde's original description, the Portsmouth shale was considered the uppermost member of the Cuyahoga (116, p. 758) at a position similar to that assigned to the Berne farther north (116, p. 657). In 1921 he revised these correlations and placed the base of the Logan below the Buena Vista and Berne members. Holden (112) followed this interpretation. Stockdale reports that Hyde later expressed uncertainty regarding these views, and apparently these correlations have not yet been satisfactorily determined. Stockdale believes that the top of the Portsmouth shale corresponds to the top of the New Providence formation and that the Rushville shale is approximately at the position of the Floyds Knob.

Except in the northern and northeastern parts of the State, the name Ohio shale has been used extensively in Ohio and southward more than half way across Kentucky. Haas has correlated the northeastern Ohio section with several zones of the Ohio shale by conodonts (102), and Campbell has recognized several of his New Albany zones in the Ohio shale of eastern Kentucky (44) so that the relations of the black shales on both sides of the northern Cincinnati arch now appear to be fairly well understood (Fig. 7).

East-central Kentucky, Column 85.—Farther south in Kentucky still younger Mississippian beds successively appear from beneath the Pennsylvanian (32). In the central and southern parts of the State the Mississippian System seems to be almost as completely represented as in the type region. All of the formations recognized here are known by names introduced from other areas, but because of many important differences in the lithologic succession the local usages of these names may differ from their original applications. The Chesterian sandstones that separate the various limestone and shale formations in western Kentucky and southern Illinois are largely lacking in this area. Some of them appear, at least locally, to be represented by shale. In general the Lower and Middle Chesterian consist of formations comparable to those recognized farther west, but they are not so sharply or accurately differentiated. In Laurel County and southward the equivalents of all of the Upper Chesterian formations have been identified in the Pennington (322). The Gasper and Ohara lime-

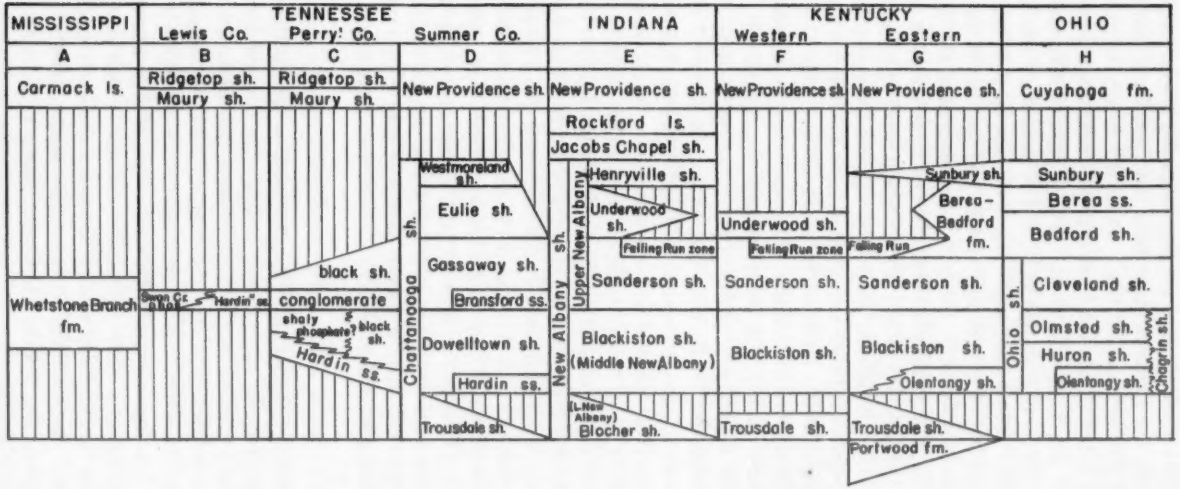

FIGURE 7.—*Correlation of New Albany shale and related formations*
After Campbell (44)

stones, as identified by Butts (32), are not equivalent to these formations as originally defined because the type Gasper appears to consist of both Renault and Paint Creek strata. The type Ohara consists of the Levias member of the Ste. Genevieve and the Renault formation (300, p. 130), and thus these names overlap. Ulrich's insistence that his Cypress sandstone, now known as the Bethel, is the basal formation of the Chesterian Series (272, p. 9) has resulted in great confusion because he and Butts generally selected a different boundary for the base of the Chesterian where that sandstone is not developed.

The Ste. Genevieve limestone appears to be present throughout eastern Kentucky, but the underlying formations of the Meramecian group pinch out northward along the outcrop. Presence of the St. Louis limestone is demonstrated by the occurrence of *Lithostrotionella*, and the Warsaw is identified by such fossils as *Talarocrinus simplex*, *Metablastus wortheni*, and *Productus* (*Marginirugus*) *magnus* (32, p. 109). In addition, the lithologic character of these formations is generally diagnostic. Stockdale recognizes the Salem in this area, but aside from the fact that beds of Salem age are doubtless present, at least locally, there seems to be small reason to separate them from the remainder of the Warsaw.

Formations from the Muldraugh down to the New Providence are based upon Stockdale's studies (254). Butts had concluded that the New Providence shale of Indiana is equivalent to both the Logan and Cuyahoga formations of Ohio (32, p. 50). However, Stockdale disagrees and has stated that the New Providence can be traced into the Cuyahoga alone (254, p. 100). This correlation is based largely upon the identification of the thin and relatively inconspicuous Floyds Knob formation, which is characterized almost everywhere by glauconitic beds. It is entirely reasonable that the New Providence and Cuyahoga are lithologically continuous, but the fact that the former is apparently more closely related to the Fern Glen whereas the latter seems to be of Kinderhookian age throws some doubt upon this correlation. Although Stockdale collected fossils at many places, he seems to have relied mostly upon lithologic characters, and possibly the boundary between the New Providence and Brodhead formations, as traced across Kentucky, does not follow exactly a uniform time horizon.

The Sunbury, Berea, and Bedford formations of the lower Waverly group thin out and disappear southward across Kentucky. A similar sequence of strata occurs, however, east of the Cumberland Plateau in Tennessee, Virginia, and West Virginia, and the Berea has been traced in the subsurface throughout much of the intervening region (205).

Central Tennessee, Column 86.—The Mississippian section of this area is quite similar to that in the neighboring part of Kentucky. Sandstones reappear in the Chesterian and have been identified as Hardinsburg and Cypress, but these correlations are not too well established. Here, as elsewhere, an unconformity probably occurs at the base of the Chesterian, but it is inconspicuous because the limestones above and below are very similar lithologically. The Tennessee Geological Survey finds the name Monte Sano limestone (derived from a locality in Alabama) useful as a designation for the undifferentiated Ste. Genevieve and "Gasper". Greater diffi-

culty appears to be encountered here in the recognition of the St. Louis and Warsaw although fossils show that beds representative of both formations are present (31). Stockdale recognizes the Salem in this area also.

Passing southward from central Kentucky, beds of Osage age become dominantly siliceous, and the name Fort Payne is commony applied to these cherty limestones. These beds cannot be subdivided readily nor are they sharply differentiated from overlying formations. Shaly strata that may occur in the lower part are referred to the New Providence, and the name Ridgetop shale (not shown on chart) has likewise been used for shale in this same position. The latter originally was considered to be K nderhookian (6, p. 146), but this age assignment has been denied. The New Providence and Ridgetop, as locally recognized, appear to be slightly different developments of beds of the same age (320).

The Maury shale has been variously considered a member of the Chattanooga shale or an independent formation. It is characterized by glauconite and phosphatic concretions. Similar beds have been recognized in Kentucky and southern Illinois and appear to pass under the typical Rockford limestone of Indiana (44).

North-central Alabama, Column 87.—The original subdivision of the Mississippian System as developed in the Southeastern States consisted of the Siliceous group below and the Mountain limestone above to which the names Fort Payne chert and Bangor limestone were later applied. The use of these names does not seem to have been consistent, and beds of Meramecian age were probably assigned to one or the other of these formations at different times or at different places. Subsequently Butts restricted the Fort Payne chert to pre-Warsaw beds overlying the Chattanooga shale thus making this formation exactly equivalent to the Lauderdale limestone of older Alabama usage (34, p. 162). He likewise restricted the Bangor limestone to beds between the Hartsell sandstone and the Pennington shale (34, p. 195). These restrictions have been accepted generally, but a few geologists continue to use the names Fort Payne and Bangor in their older and inexact senses. (See column for the northwest corner of Georgia.)

The Pennington consists of shaly strata at the top of the Chesterian succession and is recognized by its lithologic character. It generally includes conspicuous red beds. In its outcrops on the east flank of the Cincinnati arch this formation is rarely more than 200 feet thick. It generally succeeds beds of Glen Dean age in Kentucky and Tennessee, but no sharp lithologic break exists, and the locally recognized lower boundary is probably not consistent. Fossils, mainly ostracodes, suggest that the Pennington in this region includes strata ranging from Vienna to Clore in age. Kinkaid equivalents are less certainly present (322).

In Alabama the Pennington overlies the Bangor limestone that presumably includes strata of Glen Dean age in its lower part. The thickness of the Bangor, which reaches a maximum of 700 feet (34, p. 196), is probably too great, however, for Glen Dean alone, and either it continues upward locally to include beds of Menard or even later age or its lower boundary has been drawn lower than is generally supposed. Beds of Golconda age have not been identified in this area. If present they are included, presumably, in the Gasper as locally recognized, but it is almost equally possible that they occur in the lower part of the Bangor.

According to Butts the Ste. Genevieve limestone with *Platycrinites huntsvillae* is present in this area in beds that were probably formerly included in the Tuscumbia limestone. Butts, however, has restricted the use of the latter name to beds of St. Louis and Warsaw age that are not readily separable (34, p. 167).

Considerable controversy has arisen regarding the age of the Chattanooga shale. Some consider it Devonian (19, p. 182). At the other extreme Klepser concluded that it is the shoreward deposit of a southward-advancing sea varying in age from place to place and contemporaneous with formations of different lithologic character to the north. He suggested that, in northern Alabama, it may be as young as Warsaw or possibly St. Louis (138; 254, p. 55). This concept appears to be untenable because fossils of Warsaw, Osagean, and possibly Kinderhookian age occur in strata overlying the Chattanooga in Alabama (34, p. 166, 173). Also the gradation of near-shore black shale into off-shore silty deposits is exactly the reverse of the actual relationship between strata of these types westward from the late Devonian and early Mississippian delta of Pennsylvania and New York (62, p. 1734). Campbell states that all divisions of the New Albany shale with the same time limits are duplicated in the Chattanooga shale of Tennessee (44, p. 881). According to C. L. Cooper, conodonts in the Chattanooga of northern Alabama indicate the presence of strata of both early and middle New Albany age.

Northwestern Alabama, Column 88.—Sandstone believed to be of Hardinsburg age is the uppermost Mississippian formation in this area. The name Hartsell, formerly used for any and all sandstone of the upper Mississippian, has been restricted to this formation by Butts (34, p. 195). A lower sandstone, correlated with the Cypress, locally separates the Golconda from the Gasper as these are recognized here (34, p. 189). In this area the latter formation appears to be exclusively of Paint Creek age and overlies a third sandstone, correlated with the Bethel (34, p. 184). Because Butts believed that the Bethel marks the base of the Chesterian Series, underlying strata were identified as Ste. Genevieve in spite of the fact that they differ greatly in lithologic character from the Ste. Genevieve as it occurs only a short distance to the east (34, p. 178). Probably, he also included basal Chesterian strata in the Ste. Genevieve in other parts of Alabama as he suggested that *Talarocrinus*, an excellent guide fossil of the Lower Chesterian, may occur at Huntsville in beds considered uppermost Ste. Genevieve (34, p. 187).

Both true Ste. Genevieve and St. Louis limestones are believed to be absent in northwestern Alabama, and the Tuscumbia limestone probably consists of beds of Warsaw age alone (34, p. 179).

Northeastern Mississippi, Column 89.—The outcropping Mississippian formations of this area are continuous with those in northeastern Alabama, but they have been given a completely different series of local names. Strata equivalent to the restricted Fort Payne chert and Lauderdale limestone of Alabama have been termed the Carmack limestone and Iuka formation and are described as being separated by an important unconformity. Fossils reported from the Iuka suggest that this formation includes equivalents of the Keokuk, Warsaw, and St. Louis limestones, and Morse stated that some Ste. Genevieve may be present also. Fossils of the Carmack limestone generally are not well preserved, but Morse concluded that they are largely of

Kinderhookian age although this formation may continue upward to include the lower Burlington (191, p. 89).

The Whetstone Branch formation is the local designation for the Chattanooga shale which contains interbedded sandstone in this area. The occurrence of *Tentaculites* seems to prove the Devonian age of at least a part of this formation (91, p. 61), but middle New Albany conodonts have been recognized near by in Tennessee, so the upper part may be younger.

APPALACHIAN DISTRICT

Mississippian rocks outcrop along the eastern face of the Cumberland and Allegheny plateaus and in the Valley and Ridge province of the Appalachians from central Alabama to northeastern Pennsylvania, a distance of nearly 900 miles. On the south this region is contiguous with the outcrops on the flank of the Cincinnati arch, and to the north the belt of Mississippian outcrops swings west and, except for local overlap by the Pennsylvanian (313), joins the previously described region near Lake Erie. Throughout the Appalachian region the types of sediments vary considerably. At each end thick clastic sections reflect geosynclinal environments. In the middle, much limestone is present, and the stratigraphic section is similar in many ways to that developed in areas to the west.

East-Central Alabama, Column 90.—In central and eastern Alabama and the neighboring part of Georgia the upper Mississippian is represented mainly by shale. The lower part is the Floyd shale, presumably more or less equivalent to the old unrestricted Bangor limestone into which it grades laterally. Its stratigraphic position and fossils are evidence that much of this formation is of Chesterian age, but because of the scarcity of fossils the age of its lower part is not everywhere certain. The Chattanooga shale is generally absent near Birmingham, and representatives of the restricted Fort Payne chert with Kinderhookian fossils in its lowest part (34, p. 166) and Warsaw limestone have been recognized only locally. If any of the lower or middle Mississippian consists of shale in this area it is included in the Floyd (41, p. 10). The *Leiorhynchus carboniferum* fauna has been found in an unrecorded part of the Floyd and has been considered to tie this formation to the lower part of the Chesterian or possibly to the Ruddell shale of Arkansas and related beds elsewhere.

The Parkwood formation, recognized only in a comparatively small area in Alabama, at various places overlies the Pennington shale, the Bangor limestone, or the Floyd shale. The relations of these formations are not clear, and the Pennington shale may grade laterally into either or both the Floyd and the Parkwood. Also the Floyd and Parkwood may be gradational. Fossils are rare in the Parkwood, and published identifications appear to be uncertain (34, p. 206). This formation was considered by Butts to include both Mississippian and Pennsylvanian strata (41, p. 11), and the question of its age has been discussed previously. No stratigraphic break has been recognized between the Parkwood and the overlying Pennsylvanian.

Polk County, Georgia, Column 91.—The Rockmart slate or shale is a partly metamorphosed formation of great thickness. This name has been used for beds now

known as Floyd, but as currently recognized in Georgia it was long considered to be of pre-Mississippian age. A few unrecorded fossils found in it by Butts, however, suggest that at least part of the formation is Mississippian.

Northwest corner of Georgia, Column 92.—Floyd shale overlying the Chattanooga is recognized between this area and the last. In the northwestern corner of Georgia, however, the Mississippian section is very similar to that in north-central Alabama. The succession of formations recognized by Butts is not consistently applied, and the Fort Payne chert and Bangor limestone have recently been described in much the same sense as that in which they were originally proposed (259).

The type locality of the Chattanooga shale occurs near by in Tennessee, and this formation appears to consist of the same three members that are developed to much greater thickness farther northeast in Tennessee and Virginia (261).

Eastern Tennessee, Column 93.—The Mississippian System in eastern Tennessee has received little recent attention. The formations recognized here are largely lithologic and not accurately discriminated. The Grainger shale may be equivalent to and continuous with lower and middle Mississippian clastic beds that possibly are present in the Rockmart and Floyd formations on the one hand and the Cuyahoga-Price-Ponoco beds on the other. The Newman limestone is approximately equivalent to the old Bangor limestone to the south and the Greenbrier limestone to the north (36, p. 23). No break in the stratigraphic section has been recognized here but it is unlikely that the section is complete. Reger has traced several West Virginia formations southward into Tennessee, but the results of his studies have not been published.

Cumberland Gap, Tennessee, Column 94.—This column shows Butts' interpretation of the main part of the Mississippian section (32, pl., col. 46). The boundary between the Gasper and Glen Dean, as locally recognized, appears to be somewhat uncertain, and the Glen Dean here seems to include beds not present at the type locality. Butts correlated the Cuyahoga with the lower part of the New Providence, but Stockdale considers it to be equivalent to that formation in its entirety (254, p. 100). No important break has been recognized between these beds and the underlying black shale. On the whole, this section appears to be rather poorly known.

The Chattanooga shale is divided into three members in accordance with the interpretation of J. H. Swartz (261, p. 431). The age of the Cumberland Gap shale has not been determined, and it may include strata of early as well as middle New Albany age. Butts considered these beds to be the upper part of the Brallier shale (42, p. 321). The Pennington here is thin and consists only of the basal Stony Gap member (42, p. 400).

Pineville, Kentucky, Column 95.—This section is not known in detail, and the formations shown are those recognized by Butts (32 pl., col. 45). The stratigraphic development here seems to be as much like that exposed east of the Cincinnati arch as like those of eastern Tennessee, southern West Virginia, or southwestern Virginia.

Greendale syncline, Virginia, Column 96.—The Mississippian succession in this area differs only in minor respects from that recognized in the southwestern corner of the State. The Hillsdale limestone corresponds approximately to the St. Louis limestone of Butts, and the Little Valley limestone is the same as his Warsaw (42). The names Ste. Genevieve, Gasper, and Glen Dean are now used tentatively by the Virginia Geological Survey (58, p. 160), and new names may be proposed for these units later.

According to B. N. Cooper, the Cumberland Gap shale is not present in this area, and the Big Stone Gap shale overlies strata referred to the Chemung formation. Possibly the latter, as recognized here, may include beds of middle New Albany age in its upper part.

Southwestern Virginia, Column 97.—This section and that presented for southeastern West Virginia are practically identical, but the stratigraphic nomenclature of the two State geological surveys differs considerably. The type locality of the Pennington shale occurs in this area, and Reger has identified the Stony Gap sandstone as its basal member (220, p. 312). The Pennington is believed to be equivalent to the Hinton group of the Mauch Chunk (42, p. 393).

Southeastern West Virginia, Column 98.—A larger number of stratigraphic units has been recognized in this area than anywhere else in the Appalachian region (220). The Mauch Chunk Series has been minutely subdivided with adjacent shales, sandstones, limestones, and coals given the same names in many instances. The chart shows only part of the names that have been used. Some of these units are enclosed in boxes to emphasize their possible importance for correlation with the upper Chesterian type section. These correlations, however, are based on nothing more than lithologic similarity and stratigraphic position. B. N. Cooper has stated that few of these named units can be recognized except near their type localities (58, p. 173).

Correlations of this column, and also the column for southwestern Virginia, with the type section are somewhat doubtful (211, p. 253), and local miscorrelations may confuse the situation further. Also some of the fossil associations appear to be different from those known in the Mississippi Valley. *Sulcatopinna*, a pelecypod restricted to Vienna and younger formations in the type Chesterian area, has been reported from the Lillydale shale (93, p. 452; 220, p. 437), and this suggests that the type Pennington is much younger than the beds referred to that formation on the east flank of the Cincinnati arch. B. N. Cooper believes, however, that the bed in which this fossil was found was misidentified and that no such discrepancy exists. Better evidence seems to be furnished by the occurrence of large *Pentremites*, identified as *P. maccalliei*, in the Fido sandstone (42, p. 170) and lower Bluefield of Virginia. This is similar to *P. obesus* of the typical Golconda, and Cooper also reports the occurrence of *Pterotocrinus* wing plates similar to those of *P. capitalis*, another excellent Golconda species, from this same zone.

The Greenbrier limestone certainly includes Lower Chesterian beds in its upper part as proved by the presence of *Talarocrinus* (93, p. 463), and these crinoids also occur in the "Gasper" limestone of Virginia (42, p. 380). The identification of *Camarophoria* (=*Stenoscisma*) *explanata* by Girty from apparently similar beds (93,

p. 455), however, is anomalous because this species is not known below the Middle Chesterian in the type area.

B. N. Cooper believes that the Union limestone is entirely Chesterian, but Reger reported *Platycrinites huntsvillae* in its lower half (220, p. 468), indicating that this part is certainly pre-Chesterian. If sandstone in northeastern West Virginia, termed Bethel by Reger (223, p. 329), is correctly correlated, which is uncertain, the lower part of the Union limestone, termed Fredonia, must transgress the boundary between Ste. Genevieve and lower Chesterian. Cooper states that the limestones on both sides of this boundary are almost identical lithologically and can be distinguished only by their fossils.

The Hillsdale limestone carries *Lithostrotionella* (220, p. 487) and consequently is of St. Louis age, and Reger believes that the 1000 or more feet of strata separating this formation from the Union limestone are not represented in the Mississippi Valley between the Ste. Genevieve and St. Louis limestones (220, p. 452). This conclusion is improbable, however, because the latter formations are conformable in the type region, except locally on the flank of the Ozarks, and the Meramecian Series appears to be greatly expanded in thickness in this part of the Appalachian region.

The Maccrady series is a lithologic division that includes conspicuous red beds. In West Virginia it contains fossils of possible Warsaw age (93, p. 483), and in Virginia limestone with comparable fossils is distinguished as the Little Valley limestone (58, p. 157). The Maccrady is recognized in a restricted sense in Virginia (42, p. 351) and, according to Butts, is of Osagean age (42, p. 354). B. N. Cooper, however, believes that a zone of Keokuk age is indicated by *Tetracamera subtrigona* in the underlying Price and suggests that the Maccrady may be referable to the Warsaw (58, p. 153). Butts recognized no Keokuk species in the Price (42, p. 350) and concluded that an important hiatus separates the Maccrady from overlying strata (42, p. 354). Cooper states, however, that this formation seems to be conformable both above and below (58, p. 154). Because it has been recognized almost solely by lithologic features these boundaries probably have not been drawn at uniform horizons.

The problem of the Kinderhookian in most of the Appalachian region is quite perplexing. Except for black shale, which may be equivalent to the Chattanooga, no strata of that age have been recognized (42, p. 495), and an important hiatus is generally believed to separate Osagean strata from the Upper Devonian. No clear evidence of an important physical break at this position, however, has ever been described. For this and other reasons the correctness of such a conclusion is suspect, but the chart has been drawn to conform with this idea from West Virginia northward.

The Price and Pocono are approximately equivalent groups of strata of somewhat different lithologic development (42, p. 336). The Price formation carries fossils similar to the Cuyahoga of Ohio. On the basis of lithologic continuity Butts has correlated that formation with the New Providence of supposed early Osagean age (38). The reported occurrence, on the one hand, of such Keokuk species as *Pseudosyrinx gigas*, *Syringothyris textus*, and *Tetracamera subtrigona* (58, p. 150) and, on the other, of such Kinderhookian species as *Productella concentrica*, *Punctospirifer solidirostris*, *Spirifer* cf. *marionensis*, *S. striatiformis* (42, p. 348–9), *Brachythyris semiplicata*, *Spirifer missouriensis* (58, p. 150), and *Protocanites lyoni* (177) in the Price strongly

suggests that it is more inclusive than has been supposed. The Broad Ford sandstone generally has been included in the Pocono, but Butts doubted its Mississippian age at the type locality (42, p. 341), and B. N. Cooper believes that beds known by this name have been miscorrelated from place to place. Strata commonly identified as the Sunbury shale and Berea sandstone are recognized as the basal members of the Pocono in West Virginia. The correct usage of these names is somewhat doubtful (220, p. 527), but the Sunbury is reported to have been traced by subsurface records (221, p. 406), and these formations are probably of Mississippian age. Black shale apparently equivalent to this so-called Sunbury has been recognized in southwestern Virginia (58, p. 144) where it appears to correspond with the Big Stone Gap shale of Swartz (261). The relations of these beds to the underlying Devonian are not entirely clear, and possibly some of the upper strata referred to the Chemung may be equivalent to the Cumberland Gap shale and be of early Kinderhookian ages.

Randolph County, West Virginia, Column 99.—The published description of the Mississippian section occurring in this area (223) has been supplemented by additional data furnished by Reger. The section is much the same as the last except that the uppermost Bluestone beds are absent and a considerable hiatus is believed to separate the Pocono and Maccrady series.

Northwestern Virginia, Column 100.—Only the Pocono sandstone of Mississippian age is recognized here. This formation and the Price are laterally equivalent facies developments (42, p. 336), but detailed correlations are uncertain.

Western Maryland, Column 101.—The Mississippian formations in this area have received little attention in recent years. Doubtless the section is similar to that in the neighboring part of West Virginia except for the absence of much of the Meramecian Series. There are no data for the accurate correlation of subdivisions of the Pocono group as recognized here with strata in other areas.

South-central Pennsylvania, Column 102.—In Pennsylvania the recognized Mississippian rocks are divided into two groups or formations, the Pocono below and the Mauch Chunk above, neither of which corresponds with the similarly named series in West Virginia. Both names were taken from Pennsylvania localities, and presumably the present usage in this State corresponds more closely to the original than in West Virginia where these units have been restricted.

The correct interpretation of the Broadtop section is none too certain. Reger called attention to the fossiliferous Riddlesburg shale and correlated lower strata with the Broad Ford and Berea sandstones (221). Girty reported that the fauna might almost as well be Devonian as Mississippian (95, p. 112). On the basis of unpublished faunal studies, Laird places the Mississippian-Devonian boundary at the base of the Riddlesburg.

The Loyalhanna limestone of southern Pennsylvania and western Maryland commonly has been correlated with the Ste. Genevieve (33, p. 254). It is generally a calcareous nonfossiliferous sandstone and at different times has been included in

either the Mauch Chunk or Pocono. Except for its continuation with some portion of the Greenbriar series of West Virginia there is little evidence as to its age.

The Mauch Chunk formation in south-central Pennsylvania includes several calcareous beds or lenses. To one of the most conspicuous of these the name Greenbriar limestone has been applied. Correlations of this limestone, and the others also, with specific parts of the much more extensive West Virginia Greenbriar limestone are uncertain.

Harrisburg, Pennsylvania, Column 103.—Northeastward across Pennsylvania, limestones and other persistent marine zones disappear, and the Mississippian becomes a practically continuous succession of continental clastics. Its two parts are distinguished by lithologic characters, and it is not certain that they have been separated consistently from place to place. Possibly strata equivalent to the Maccrady series of West Virginia have been included in either or both of these units.

Northeastern Pennsylvania, Column 104.—The type localities of the Mauch Chunk and Pocono groups or formations occur in this region. Both are lithologic units that contain no fossils except plants. Controversy has arisen over the type locality and age of the Pocono. This name was derived from the Pocono Mountains and Plateau, and it has been applied very widely to strata of supposed early Mississippian age in Pennsylvania, West Virginia, Maryland, and Virginia. Much of the sandstone in the Pocono region is now known to be Devonian (48, p. 138), and Chadwick contends that the continued use of this name for Mississippian strata is unwarranted. Willard states that the type locality of the Pocono is in the Music Mountains where sandstone of Mississippian age is present, and he holds that the application of this name to Mississippian beds is proper (312, p. 304). Regardless of the type locality, however, and the age of the rocks at that place, the name Pocono has been used almost exclusively for strata believed to be of early Mississippian age. Thus the retention of this name for a lithologic formation seems to be justified.

NORTHERN APPALACHIAN BASIN—SUBSURFACE

COLUMNS 105–107

This region includes the earliest-developed oil and gas fields of North America, and thousands of wells have been drilled through the Mississippian rocks in Pennsylvania, West Virginia, and eastern Ohio. The stratigraphic section encountered here is largely clastic, and the productive Mississippian sands are more or less irregular developments in the Waverly group of Ohio or equivalent Pocono group of Pennsylvania. One or two limestones, of great importance for correlation, overlie these beds. The Big Lime of the drillers connects the Maxville limestone of Ohio with a part of the Greenbriar of West Virginia (160, p. 1028; 222, p. 591). The Big Injun sand is very regular in distribution but varies greatly in thickness and connects the Logan formation of Ohio with the Burgoon sandstone of Pennsylvania (37, p. 76). The Squaw sand is rather erratic, and possibly several different sand lenses in this general part of the section have been correlated. The Berea sand persists throughout much

of this region (205). Not only is it productive but also it is a useful datum for the identification and correlation of underlying Devonian sands. Other sand bodies of less extent are the Keener, reported in Ohio, Pennsylvania, and West Virginia, the Wier of West Virginia, which has been correlated with the outcropping Broad Ford sandstone (222, p. 4.9), and others that are restricted to smaller areas.

NEW ENGLAND

COLUMN 108

No Mississippian rocks have been identified with certainty in New England, and few geologists believe that beds of this age are present in the complex of Paleozoic metamorphics and volcanics which extend intermittently from Rhode Island to Maine. It is now fairly well established at several places that these rocks can be divided into two general groups. The older group has yielded fossils ranging in age from Cambrian to Devonian. The younger group is generally considered to be "Carboniferous" (Mississippian to Permian inclusive) although early Paleozoic or even pre-Cambrian age has been inferred locally by some writers. These younger metamorphics are preserved in a series of structural basins more or less in line with others which contain known Mississippian rocks in New Brunswick. Both there, and southwest in Pennsylvania, thick clastic coal-bearing Mississippian sections are present, and the occurrence of poorly preserved *Calamites*-like stems and other similar plant fossils is not sufficient evidence to disprove that the younger New England metamorphics are not of Mississippian age at least in part.

In the Narragansett and Norfolk basins of Rhode Island and eastern Massachusetts the Pondville conglomerate, with *Calamites* (85, p. 77), is overlain successively by the Wamsutta formation, also with *Calamites* (325, p. 29), and the coal-bearing Rhode Island formation. All are Carboniferous and generally considered Pennsylvanian, but their ages have not been determined definitely.

In the Boston Bay area the Mattapan (and Lynn) volcanics are overlain by (11, p. 104) or grade upward into (85, p. 201) the Roxbury conglomerate with *Cordaites* or *Lepidodendron* (141, p. 41). These also are probably Pennsylvanian, but their age is not certainly known.

In the Worcester region of central Massachusetts the Oakdale quartzite underlies the Worcester phyllite containing poorly preserved plant fossils. White stated that they are definitely Carboniferous and added that he "suspected that further discoveries will show the beds to be of Pennsylvanian, possibly Pottsville, age" (307). These strata appear to be equivalent to more highly metamorphosed rocks in several near-by areas where they are known by a variety of names (85, p. 60).

Strata probably continuous with those of the Worcester region extend southward into Connecticut (85, p. 49; 224, p. 114) and northeastward into New Hampshire and southern Maine. In New Hampshire they have been termed the Merrimack group (111, p. 588) and they are known as the Casco Bay group in Maine (125, p. 170). Both have been locally subdivided or restricted.

The plant-bearing Perry formation of southeastern Maine, correlated for many years with the Carboniferous of New Brunswick, was determined by White to be of

late Devonian age (242, p. 83) but is shown on the more recent geologic map of the State as Mississippian (127). Leavitt and Perkins (149, p. 8) also considered it Mississippian.

The White Mountain magma series, which is extensively developed throughout New Hampshire (13, p. 267), is regarded by Billings as a plutonic phase contemporaneous with the Moat volcanics (12, p. 918). Likewise the Quincy granite and the Blue Hills porphyry of the Boston region (141, p. 35) are contemporaneous with the Mattapan (and possibly the Lynn) volcanic complex. Billings believes that the named igneous groups in New Hampshire are consanguineous with those in the Boston area and therefore presumably are contemporaneous with them. In the White Mountains the Moat volcanics rest unconformably upon strongly metamorphosed lower Devonian strata and therefore are younger than the Acadian disturbance of late Devonian time. In the Boston region, and in Rhode Island, the Mattapan volcanics are unconformably overlain by the Pondville conglomerate, which is at the base of the thick Carboniferous detrital sediments. The Pondville is either early Pennsylvanian or possibly Mississippian, and the underlying volcanics can hardly be younger than Mississippian. Accordingly, the named igneous rocks are probably post-Devonian and pre-Pennsylvanian—*i.e.*, Mississippian.

EASTERN CANADA AND NEWFOUNDLAND

The Mississippian rocks in this region consist of a thick sequence of mainly clastic strata that accumulated in a number of more or less local basins. They appear to have been derived from near-by sources, probably to the west. In general they are divisible into three parts: the Horton group below, the Windsor group, and the Canso group above. The Horton group, which may attain a thickness of 10,000 feet, consists of fluvial and alluvial sediment with some local oil shale, petroliferous sand, and evaporites. Fossils are scarce and nonmarine, and the meager flora appears to be of Pocono age (308, p. 146).

The Windsor group consists of two parts, the upper one of which overlaps locally onto pre-Carboniferous rocks. This group records one or more marine invasions, but the seaways were shallow and shifting and in few places persisted throughout all of Windsor time. Marine limestones are associated with evaporites and various types of clastics including red beds.

The Canso group is entirely nonmarine, but conglomerates are generally absent. Its flora is of late Mississippian (Lower Namurian) age, and the floras of overlying beds are distinctly different (9, p. 24).

The structure of this region is complex, and lateral changes in the lithologic characters of all groups are pronounced. To meet the needs of mapping in local areas a considerable number of more or less equivalent or overlapping stratigraphic units have been named.

Igneous activity occurred during the Mississippian period, but its history is not well known. Volcanic ash is present in New Brunswick, basaltic flows in Nova Scotia, basic pyroclastics in the Magdalen Islands, and acidic intrusions near Five Islands.

Little direct evidence is available for the correlation of the Mississippian forma-

tions of this region with other parts of North America. The Windsor faunas are of north Atlantic derivation and appear to be more closely related to European faunas than to those of the interior of this continent (7, p. 65). Correlations indicated on the chart are tentative and general. They are based upon the Namurian-Viséan and the Upper and Middle Viséan boundaries as determined here (7, p. 71) and on the position at which these same boundaries are supposed to occur elsewhere in North America. Probably the Windsor group includes beds of both Meramecian and Chesterian age, but it is uncertain that the boundary between these series corresponds to the boundary between the Lower and Upper Windsor groups.

St. John, New Brunswick, Column 109.—The presence of *Micheevia corrugata* and *Aneimites acadica* in the Kennebecasis formation which consists mostly of red sandstone, shale, and conglomerate indicates its equivalence to some part of the Horton group (1, p. 30). The Upham formation consists largely of gypsum and limestone and therefore is believed to be of Windsor age. It does not occur in normal contact with undoubted Kennebecasis beds, and no fossils have been discovered in it. The Hammond River formation resembles the Kennebecasis in containing much coarse red clastic material. Although it is unfossiliferous it is believed to be equivalent to the lower part of the Hopewell group.

The Mispek Series consists of clastic sediments, extrusive volcanics, and tuff, all more or less metamorphosed. Its relations to the section outlined above have not been determined, but *Cordaites*-like fragments (1, p. 33) in the lower part indicate its Carboniferous age, and it may be partly or wholly Mississippian.

Albert-Hillsborough area, New Brunswick, Column 110.—Mississippian strata in this area reach a thickness of more than 10,000 feet and consist partly of thick fan-conglomerates (9, p. 54). The Memramcook, Albert, and Weldon formations carry *Micheevia corrugata* (330, p. 9) and are of Horton age. Entire specimens of paleoniscid fishes occur in the lower part of the Albert, whereas only isolated scales of similar fishes have been found in the Horton Bluff formation of the Horton-Windsor area. The upper part of the Albert formation includes a thick lens of rock salt and Glauber's salt suggesting its correlation with the Cheverie which likewise records semiarid conditions.

Bell reports that no fossils have been found in the Hillsborough formation, but it may be equivalent to the lower part of the Windsor group as suggested by Wright (330, p. 22).

The Hopewell group as originally defined included the Demoiselle conglomerate at its base. This formation, however, contains cobbles of fossiliferous Lower Windsor limestone and, in its lower part, two tongues of arenaceous Upper Windsor limestone. The Maringouin formation is also considered to be of Upper Windsor age either wholly or in part. It grades upward into the Shepody formation of Canso age.

The Hopewell group includes red clastic rocks that disconformably succeed the Shepody formation. These beds are of Pennsylvanian age and correspond to the lower part of the Riversdale group of other areas.

A very similar section occurs in the Joggins area of Nova Scotia except that strata below the Windsor group are not exposed.

Horton-Windsor area, Nova Scotia, Column 111.—This is the type area of Mississip-

pian rocks in eastern Canada where this system was first studied by Sir William Dawson and C. F. Hartt. Fossils are more abundant here than elsewhere, but the strata are cut by so many faults, and outcrops are so scattered that the stratigraphic sequence, particularly in the marine part of the Mississippian, can be ascertained only with difficulty. However, a two-fold division of the Windsor group is well established on faunal evidence and is applicable throughout the maritime region. The upper division is characterized by the presence of *Martinia galataea* and probably also by certain productids and clisiophyllid and other columella-bearing corals. The lower division contains many pelecypods and gastropods, indicators of facies rather than of time, and is characterized by the presence of *Composita davidsoni*, *Cranaena tumida*, and certain bryozoans. Further subdivisions have also been made, but it is not known that these zones are of regional application (7, p. 46, 71). Windsor sediments record peculiar and rapidly changing environmental conditions. Beds of gypsum and anhydrite recur throughout most of the Windsor group, and faunas were almost certainly strongly influenced by varying salinity.

Below the Windsor group is the thick Horton group, consisting of intercalated fluvial and fluvio-lacustrine sediments. It is divisible into the lower dominantly gray Horton Bluff formation and the upper dominantly red Cheverie formation. Plant remains occur in both, and there are many fossil soil beds, some supporting upright stems. *Micheevia corrugata* and *Aneimites acadica* occur in both formations (7, p. 35, 41), but Bell reports that fragments representing several sphenopterid genera (e.g., *Triphyllopteris*) present in the Cheverie formation are unknown below.

Parrsboro, Nova Scotia, Column 112.—In this area the West Bay formation of the Canso group consists of both dark-gray and red shales with thin sandstone layers. It appears to succeed very late Windsor strata conformably. Whatever lower Mississippian may be present is not exposed (9, p. 9).

Merigomish area, Nova Scotia, Column 113.—Two formations of late Windsor age are recognized in this area. Both consist of red and gray clastic sediments, but the McAras Brook contains several amygdaloidal lava flows, and limestone and calcareous shale 20 feet thick mark the base of the Ardness formation. Marine fossils, including *Martinia galataea*, occur in several zones. Overlying nonfossiliferous beds of the Lismore formation are similar lithologically to succeeding Pennsylvanian beds and appear to represent transition from a marine to a nonmarine environment.

Lake Ainslie, Nova Scotia, Column 114.—Beds of the Horton group in this area consist of two parts, coarse gray arkosic grits and conglomerates below and red and gray sandstone and shale above. At the top is the thick gray Ainslie sandstone member. These are succeeded unconformably by the Windsor group consisting of red shale, limestone, dolomite, anhydrite, gypsum, and rock salt. Fossils are much less abundant than in the Horton-Windsor area, but Bell states that faunules representing both the A and B zones of the type area have been recognized. Higher beds carry Upper Windsor species. The Mabou formation is clastic except for some thin calcareous beds near the base.

Sydney, Nova Scotia, Column 115.—The Windsor group in this area shows remarkable lateral variations, largely resulting from the local presence of fanglomerates. Zone B of the Lower Windsor overlies pre-Carboniferous rocks. It is massive lime-

stone, tongues of which wedge into the Grantmire conglomerate. Zone C varies from coarse red clastics to a succession dominated by limestone, anhydrite, and gypsum. Higher beds contain limestones and dolomites that are more widespread. The St. Anne formation is mainly arkosic sandstone and red shale with a few thin limestone bands. Pebbles near its base carry Lower Windsor fossils, and it is considered to be of Late Windsor age (9, p. 11).

The Canso group is represented by two equivalent clastic formations, the Point Edward which is dominantly red and the Cape Dauphin which is largely gray.

Port au Port, Newfoundland, Column 116.—Lower Windsor beds with a meager fauna occur at Boswarlis. Fossils suggest comparison with Zone B of the type section but are not sufficient for exact correlation (104, p. 15).

Upper Windsor limestone with *Martinia galataea* fills erosion fissures in Ordovician limestone at Aguathuna (104, p. 19).

Codroy area, Newfoundland, Column 117.—The presence of *Micheevia corrugata* and a few other plants in the Anguille series demonstrates the late Horton age of these beds. The lower part of the Codroy series is gypsiferous and is considered to be equivalent to the lower or middle part of the Windsor group. Thick overlying strata have no lithologic counterpart in Nova Scotia, but the fauna is of Late Mississippian age, and several species are characteristic of Zone E of the type Windsor (104, p. 14). The uppermost beds appear to record alternating marine and brackish- or fresh-water conditions. A well-marked lithologic break separates the Woody Cove and Woody Point beds. The latter are mainly nonmarine sandstone with *Calamites* and are correlated with the Canso group of Nova Scotia.

ARCTIC ISLANDS

Exploring expeditions in the far north have furnished meager information regarding the widespread occurrence of Carboniferous and Permian strata, particularly in the Parry Islands, the northeastern part of Ellesmere Island, and east and northeast Greenland. Most of the data available are quite unsatisfactory, and there are few places where the Mississippian System is recognizable with certainty.

Eastern Greenland, Column 118.—Carboniferous and Permian strata occur at several localities along the east coast of Greenland (267, p. 124). The Mt. Pictet formation consists of plant- and coal-bearing clastics. It is of Mississippian, and probably early Mississippian, age (228, p. 35). This appears to be overlain and overlapped by the gypsum-bearing Foldvik Creek formation that has been assigned to the lowermost Carboniferous (139, p. 244) but is now believed to be Permian because it grades upward into limestone with supposed Permian fossils (196, p. 39).

Northeast Ellesmere Island, Column 119.—The occurrence of limestone containing a coral identified as *Lithostrotion* (86, p. 610) and a *Spirifer* resembling *S. grimesi* (86, p. 628) suggests the presence of Meramecian and Osagean strata. The beds here seem to differ greatly from those in east Greenland, and they are probably more closely related to the deposits of the continental interior or Alaska.

Southern Melville Island, Column 120.—Sandstone and shale with thin beds of coal, carbonized plant remains, and a few apparently brackish-water invertebrates (172, p. 402) are widely distributed here and in neighboring areas. The age of these strata

has not been determined satisfactorally, but they are probably early Mississippian, because they are believed to pass beneath "Carboniferous" limestone to the northwest (172, p. 440). This limestone carries "*Lithostrotion*" on northern Bathhurst Island (172, p. 455), and "*Fusulina*" is reported from North Devon Island (172, p. 456). On the northern part of Melville Island gypsum occurs between the sandstone and limestone (172, p. 445).

This succession of strata, which constitutes much of the bedrock in the Parry Islands, may be a continuation of the Noatak and Lisburne formations of northern Alaska extending northeastward from Banks Island to northern Ellesmere Island. The occurrence of gypsum on the northern part of Melville Island also suggests comparison with the east Greenland section, but there no Mississippian limestone has been recognized.

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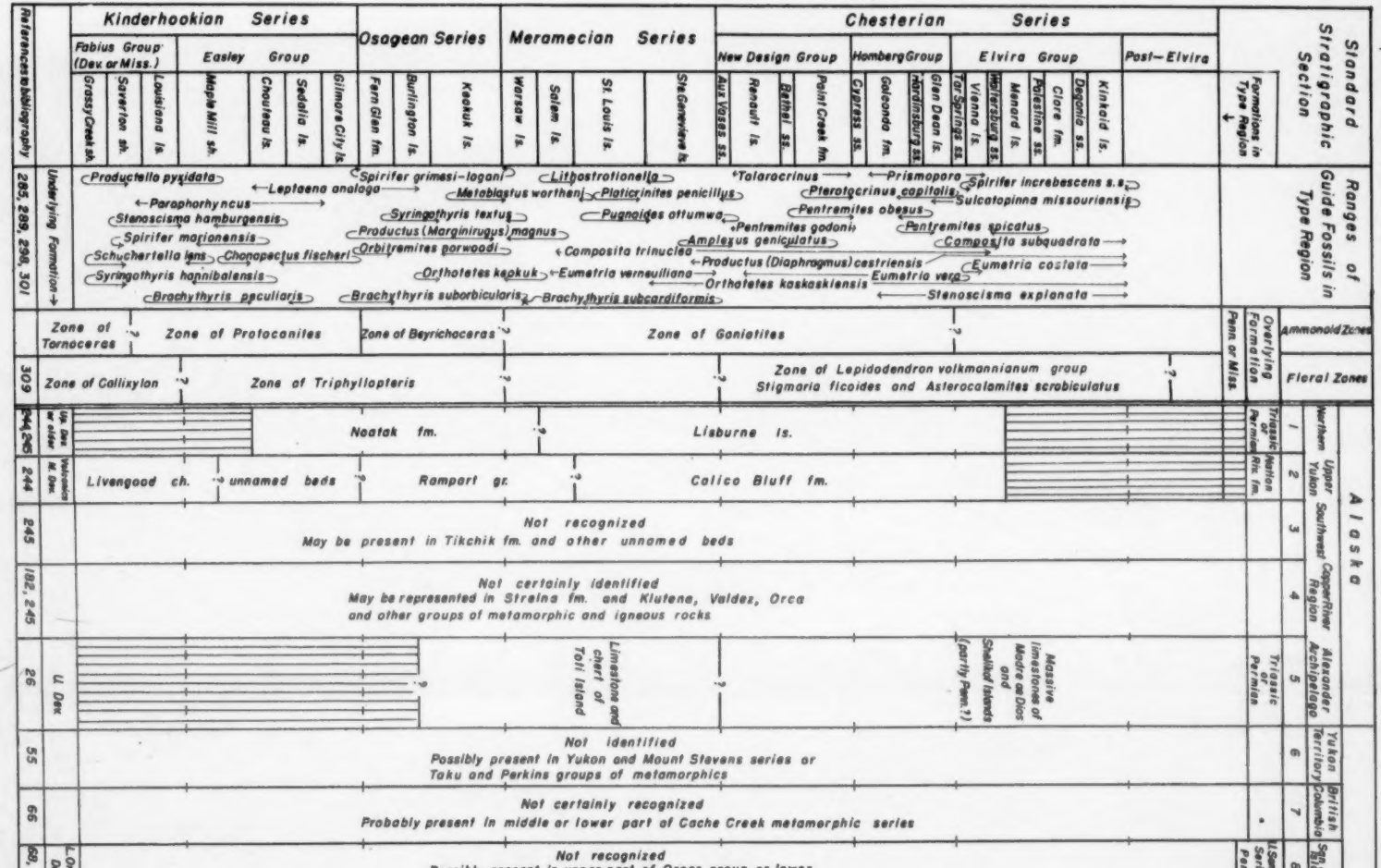
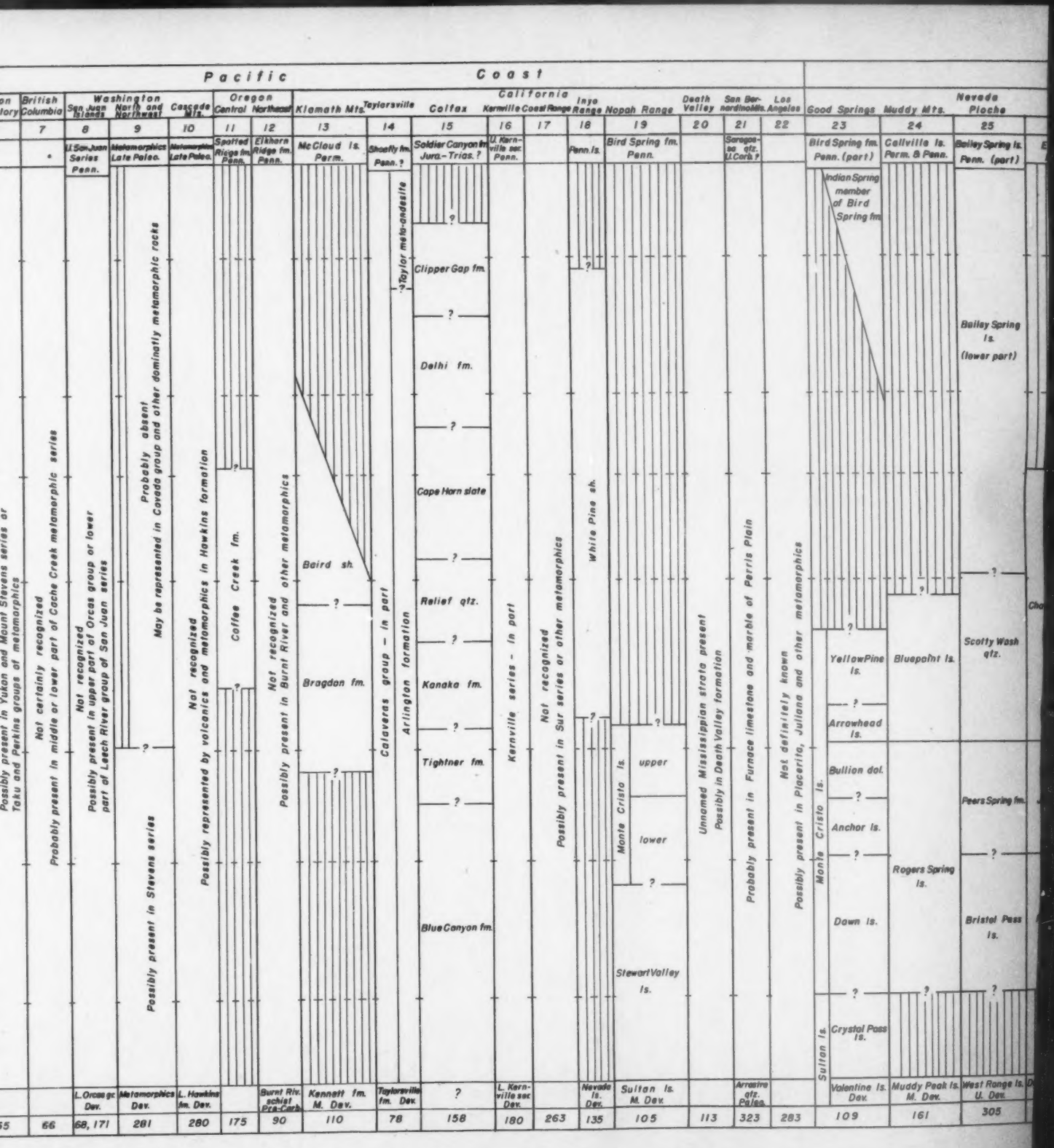
n. Philos.
st-central
so Moun-
aja Coli-
ett basin,
c. Petrol.
18.
, Alaska,
, vol. 61,
129.


Standard Stratigraphic Section
Kinderhookian Series
Fabius Group (Dev. or Miss.)
Easley Group
Osagean Series
Meramecian Series
Chesterian Series
New Design Group
Homberg Group
Elvira Group
Post-Elvira
Grassy Creek sh.
Saverton sh.
Louisiana ls.
Maple Mill sh.
Chouteau ls.
Sedalia ls.
Gilmore City ls.
Fern Glen fm.
Burlington ls.
Kaskaskia ls.
Warsaw ls.
Salem ls.
St. Louis ls.
Ste Genevieve ls.
Aux Vases ss.
Renault ls.
Bethel ss.
Point Creek fm.
Cypress ss.
Golconda fm.
Hardinsburg ss.
Glen Dean ls.
Tar Springs ss.
Haney sburg ss.
Vienna ls.
Menard ls.
Palestine ss.
Clore fm.
Degonia ss.
Kinkaid ls.
Formations in Type Region
Ranges of Guide Fossils in Type Region
References to bibliography
Underlying Formation
285, 289, 296, 301
Productella pyxidata
Leptaena analoga
Paraphorhynchus
Stenoscisma hamburgensis
Spirifer morrisonensis
Schuchertella lens
Chonopectus fischeri
Syringothyris hannibalensis
Brachythyris peculiaris
Spirifer grimesi-logani
Lithostrotionella
Metablastus wortheni
Platicrinites penicillus
Syringothyris textus
Pugnoides attumwa
Productus (Marginirugus) magnus
Orbitremites norwoodi
Orthotetes kaskaskiensis
Brachythyris suborbicularis
Brachythyris subcardiformis
Talarocrinus
Prismopora
Pterotocrinus capitalis
Pentremites obesus
Pentremites godoni
Amplexus geniculatus
Composita trinucleo
Productus (Diaphragmus) cestriensis
Eumetria vera
Eumetria verneuiliana
Spirifer increbescens s.s.
Sulcatopinna missouriensis
Pentremites spicatus
Composita subquadrata
Eumetria costata
Stenoscisma explanata
Zone of Tornoceras
Zone of Protocanites
Zone of Beyrichoceras
Zone of Goniatites
Overlying Formation
Penn. or Miss.
Ammonoid Zones
Floral Zones
309
Zone of Callixylon
Zone of Triphyllopteris
Zone of Lepidodendron volkmannianum group
Stigmaria ficoides and Asterocalamites scrobiculatus
Alaska
Northern
Upper Yukon
Southwest
Copper River Region
Alexander Archipelago
Yukon Territory
British Columbia
Lo. Dev. or older
Neatak fm.
Lisburne ls.
Triassic or Permian
Nation Riv. fm.
244, 245
Devonian or Lo. Dev.
Livengood ch.
unnamed beds
Rampart gr.
Colico Bluff fm.
244
245
Not recognized
May be present in Tikchik fm. and other unnamed beds
182, 245
Not certainly identified
May be represented in Strelna fm. and Klutene, Valdez, Orca and other groups of metamorphic and igneous rocks
26
U. Dev.
Limestone and chert of Toti Island
Massive limestones of Madre de Dios and Shakilkof Islands (partly Penn.?)
Triassic Permian
55
Not identified
Possibly present in Yukon and Mount Stevens series or Taku and Perkins groups of metamorphics
66
Not certainly recognized
Probably present in middle or lower part of Cache Creek metamorphic series
60,
Not recognized


Pacific Coast
British Columbia
Washington
San Juan Islands
North and Northwest
Cascade Mts.
Oregon
Central
Northeast
California
Klamath Mts.
Taylorsville
Colfax
Kernville
Coast Ranges
Inyo Range
Nopah Range
Death Valley
San Bernardino Mts.
Los Angeles
Nevada
Good Springs
Muddy Mts.
Pioche
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
U. San Juan Series Penn.
Metamorphics Late Paleo.
Metamorphics Late Paleo.
Spotted Ridge fm. Penn.
Elkhorn Ridge fm. Penn.
McCloud ls. Perm.
Shoofly fm. Penn.?
Soldier Canyon fm. Jura.–Trias.?
U. Kernville sec. Penn.
Penn. ls.
Bird Spring fm. Penn.
Saragosa qtz. U. Carb.?
Bird Spring fm. Penn. (part)
Callville ls. Perm. & Penn.
Bailey Spring ls. Penn. (part)
Not certainly recognized
Probably present in middle or lower part of Coche Creek metamorphic series
Not recognized
Possibly present in upper part of Orcas group or lower part of Leech River group of San Juan series
Possibly present in Stevens series
Probably absent
May be represented in Cavada group and other dominatly metamorphic rocks
Not recognized
Possibly represented by volcanics and metamorphics in Hawkins formation
Coffee Creek fm.
Not recognized
Possibly present in Burnt River and other metamorphics
Baird sh.
Bragdon fm.
Taylor meta-andesite
Calaveras group – in part
Arlington formation
Clipper Gap fm.
Delhi fm.
Cape Horn slate
Relief qtz.
Kanaka fm.
Tightner fm.
Blue Canyon fm.
Kernville series – in part
Not recognized
Possibly present in Sur series or other metamorphics
White Pine sh.
Monte Cristo ls.
upper
lower
Stewart Valley ls.
Unnamed Mississippian strata present
Possibly in Death Valley formation
Probably present in Furnace limestone and marble of Perris Plain
Not definitely known
Possibly present in Placerita, Juliana and other metamorphics
Indian Spring member of Bird Spring fm
Yellow Pine ls.
Arrowhead ls.
Bluepoint ls.
Bailey Spring ls. (lower part)
Scotty Wash qtz.
Monte Cristo ls.
Bullion dol.
Anchor ls.
Down ls.
Sultan ls.
Crystal Pass ls.
Rogers Spring ls.
Peers Spring fm.
Bristol Pass ls.
L. Orcas gc Dev.
Metamorphics Dev.
L. Hawkins fm. Dev.
Burnt Rhr. schist Pre-Carb.
Kennett fm. M. Dev.
Taylorsville fm. Dev.
?
L. Kernville sec. Dev.
Nevada ls. Dev.
Sultan ls. M. Dev.
Arrastre qtz. Paleo.
Valentine ls. Dev.
Muddy Peak ls. M. Dev.
West Range ls. U. Dev.
55
66
68, 171
281
280
175
90
110
78
158
180
263
135
105
113
323
283
109
161
305

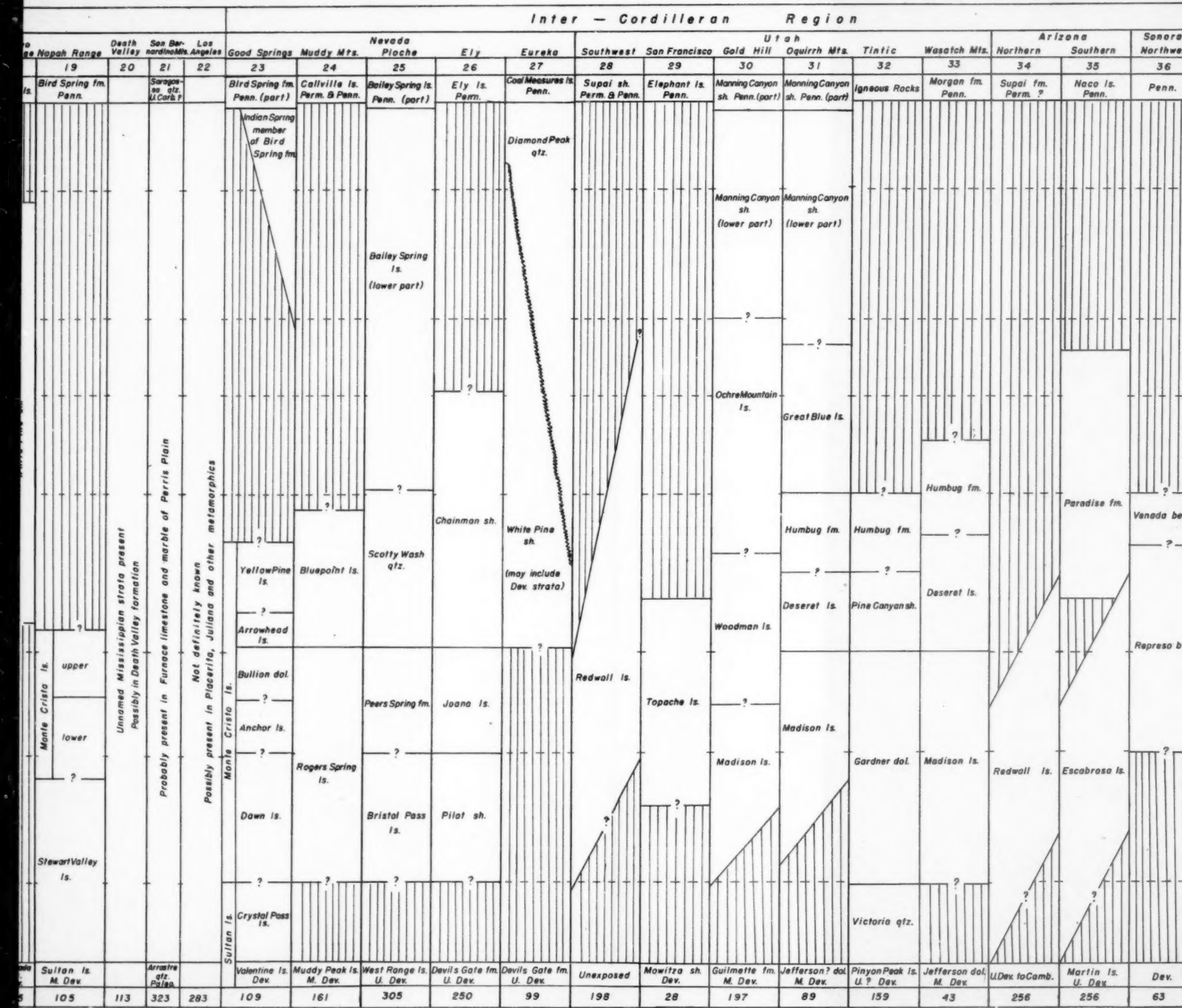
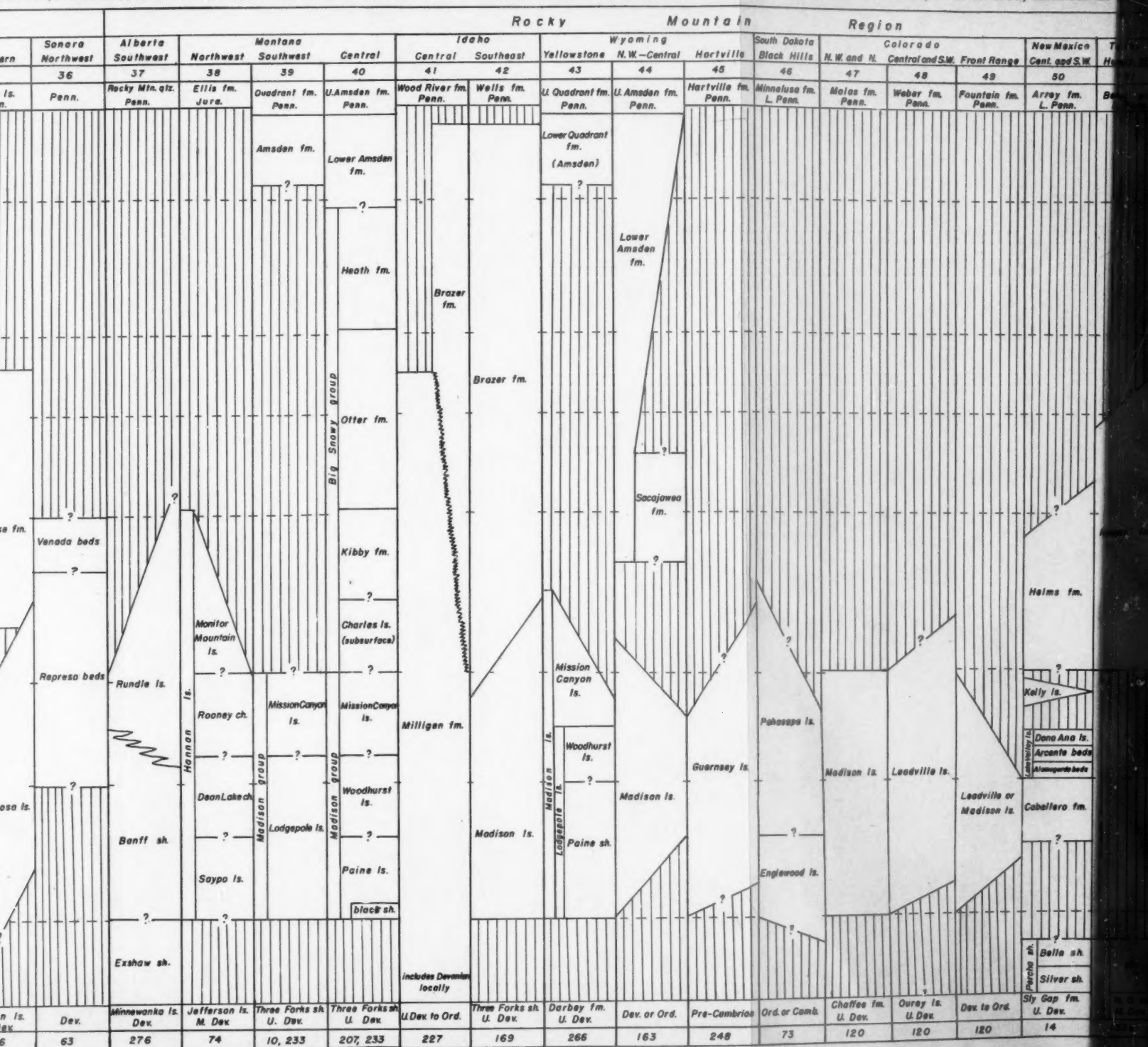

Inter — Cordilleran Region
Nopah Range
Death Valley
San Bar-dino Mts.
Los Angeles
Nevada
Utah
Arizona
Sonora
Northwe
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
Bird Spring fm. Penn.
Saragosa qtz. U. Carb. ?
Good Springs
Muddy Mts.
Pioche
Ely
Eureka
Southwest
San Francisco
Gold Hill
Oquirrh Mts.
Tintic
Wasatch Mts.
Northern
Southern
Bird Spring fm. Penn. (part)
Callville ls. Perm. & Penn.
Bailey Spring ls. Penn. (part)
Ely ls. Perm.
Coal Measures ls. Penn.
Supai sh. Perm. & Penn.
Elephant ls. Penn.
Manning Canyon sh. Penn.(part)
Manning Canyon sh. Penn. (part)
Igneous Rocks
Morgan fm. Penn.
Supai fm. Perm. ?
Naco ls. Penn.
Penn.
Indian Spring member of Bird Spring fm.
Diamond Peak qtz.
Bailey Spring ls. (lower part)
Manning Canyon sh. (lower part)
Manning Canyon sh. (lower part)
Humbug fm.
Paradise fm.
Yellow Pine ls.
Bluepoint ls.
Scotty Wash qtz.
Chainman sh.
White Pine sh.
(may include Dev. strata)
Ochre Mountain ls.
Great Blue ls.
Humbug fm.
Humbug fm.
Deseret ls.
Arrowhead ls.
Deseret ls.
Pine Canyon sh.
Monte Cristo ls.
upper
lower
Bullion dol.
Anchor ls.
Dawn ls.
Redwall ls.
Topache ls.
Woodman ls.
Madison ls.
Madison ls.
Gardner dol.
Madison ls.
Redwall ls.
Escabrosa ls.
Stewart Valley ls.
Rogers Spring ls.
Peers Spring fm.
Joana ls.
Bristol Pass ls.
Pilot sh.
Sultan ls.
Crystal Pass ls.
Victoria qtz.
Sultan ls. M. Dev.
Valentine ls. Dev.
Muddy Peak ls. M. Dev.
West Range ls. U. Dev.
Devils Gate fm. U. Dev.
Devils Gate fm. U. Dev.
Unexposed
Mowitza sh. Dev.
Guilmette fm. M. Dev.
Jefferson? dol. M. Dev.
Pinyon Peak ls. U. ? Dev.
Jefferson dol. M. Dev.
U.Dev. to Camb.
Martin ls. U. Dev.
Dev.
105
113
323
283
109
161
305
250
99
198
28
197
89
159
43
256
256
63
Unnamed Mississippian strata present
Possibly in Death Valley formation
Probably present in Furnace limestone and marble of Perris Plain
Not definitely known
Possibly present in Placerita, Juliana and other metamorphics

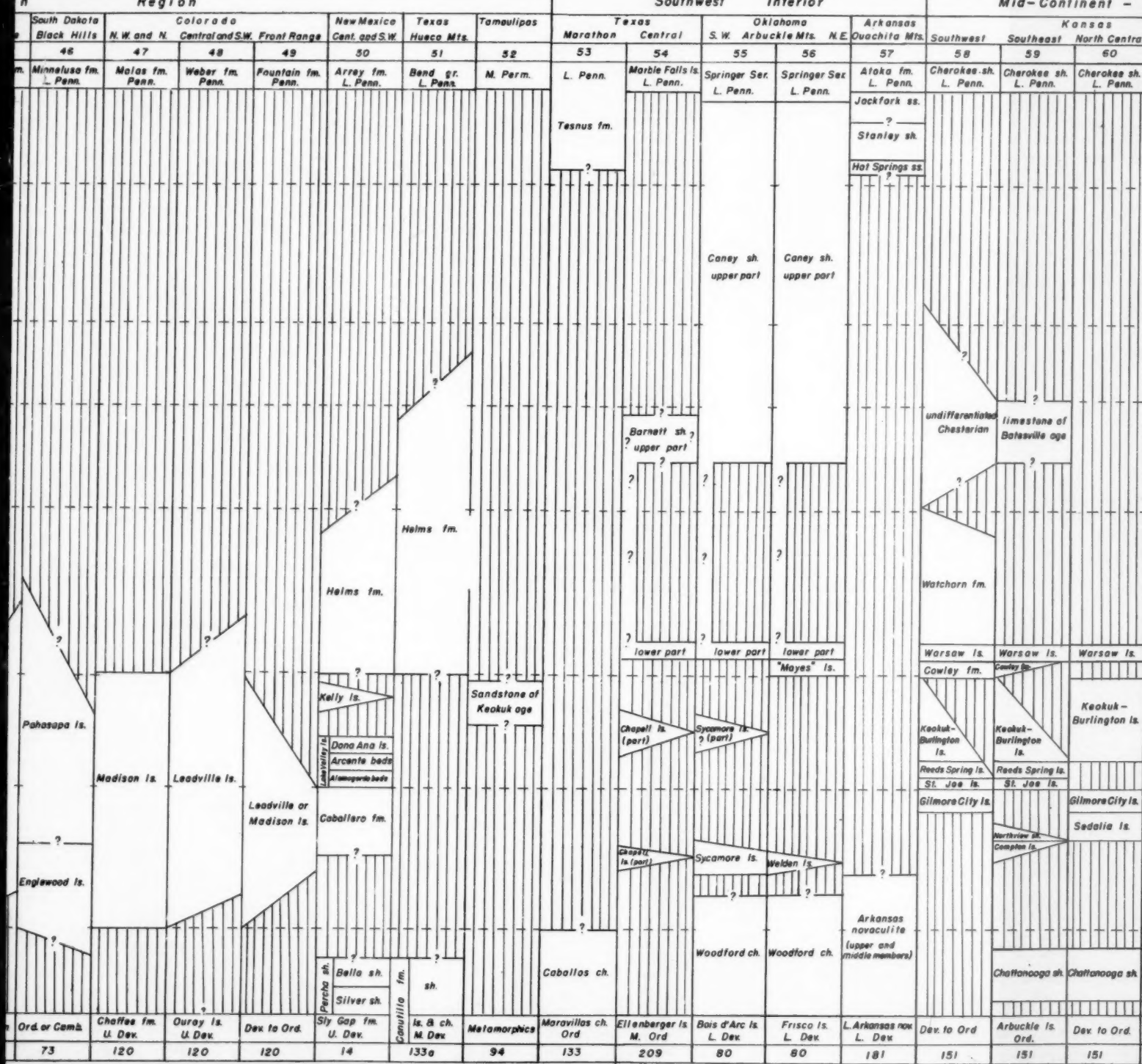
CHART NO. 5.- CORRELATION OF THE MISSISSIPPIAN FORMATIONS OF NORT

Veller (Chairman), James Steele Williams, Walter A. Bell, Carl O. Dunbar, Lowell R. Laudon, Raymond C. Moore, Paris B. Stockdale, P. S. Warren, Kenneth E.

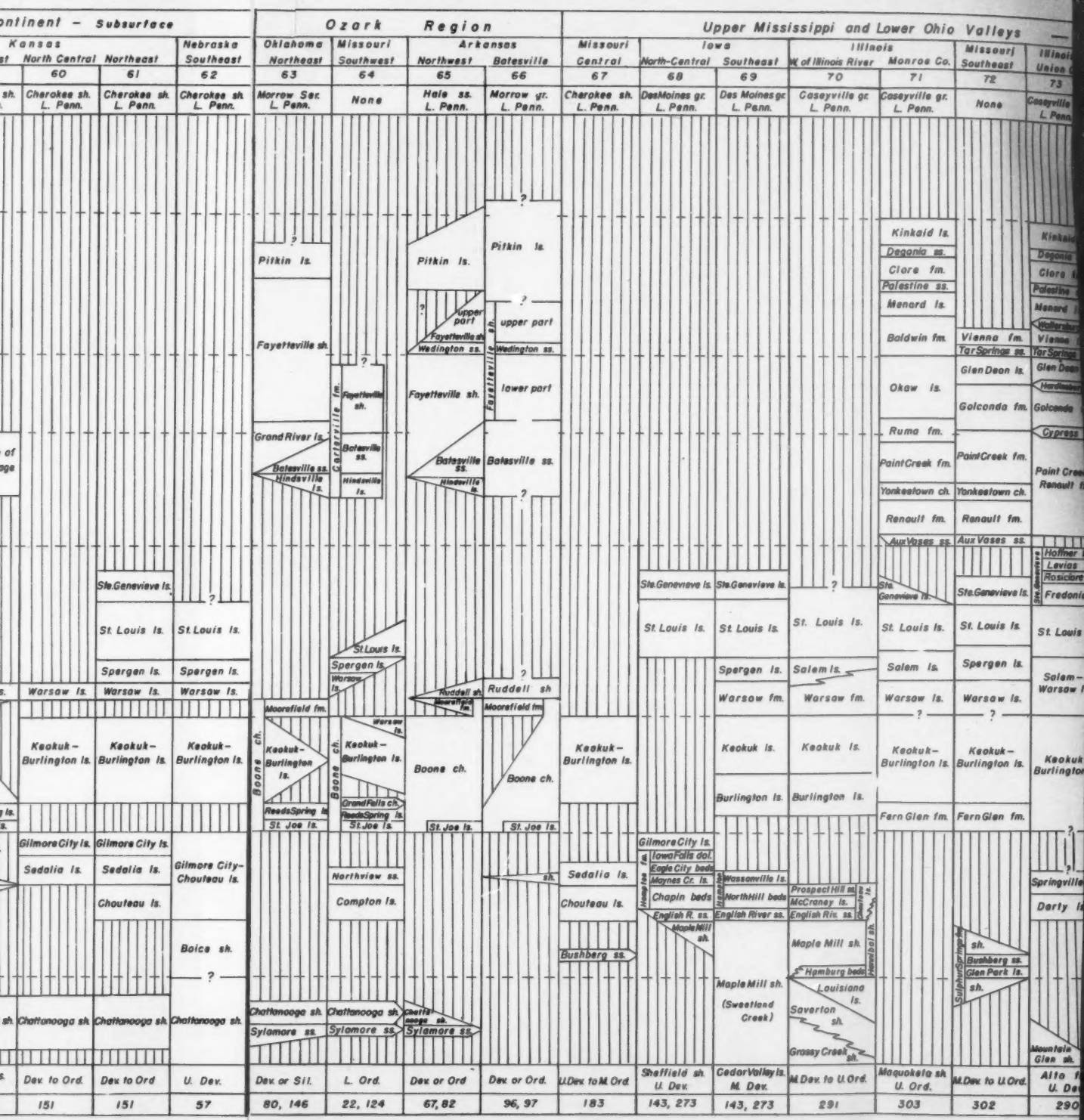


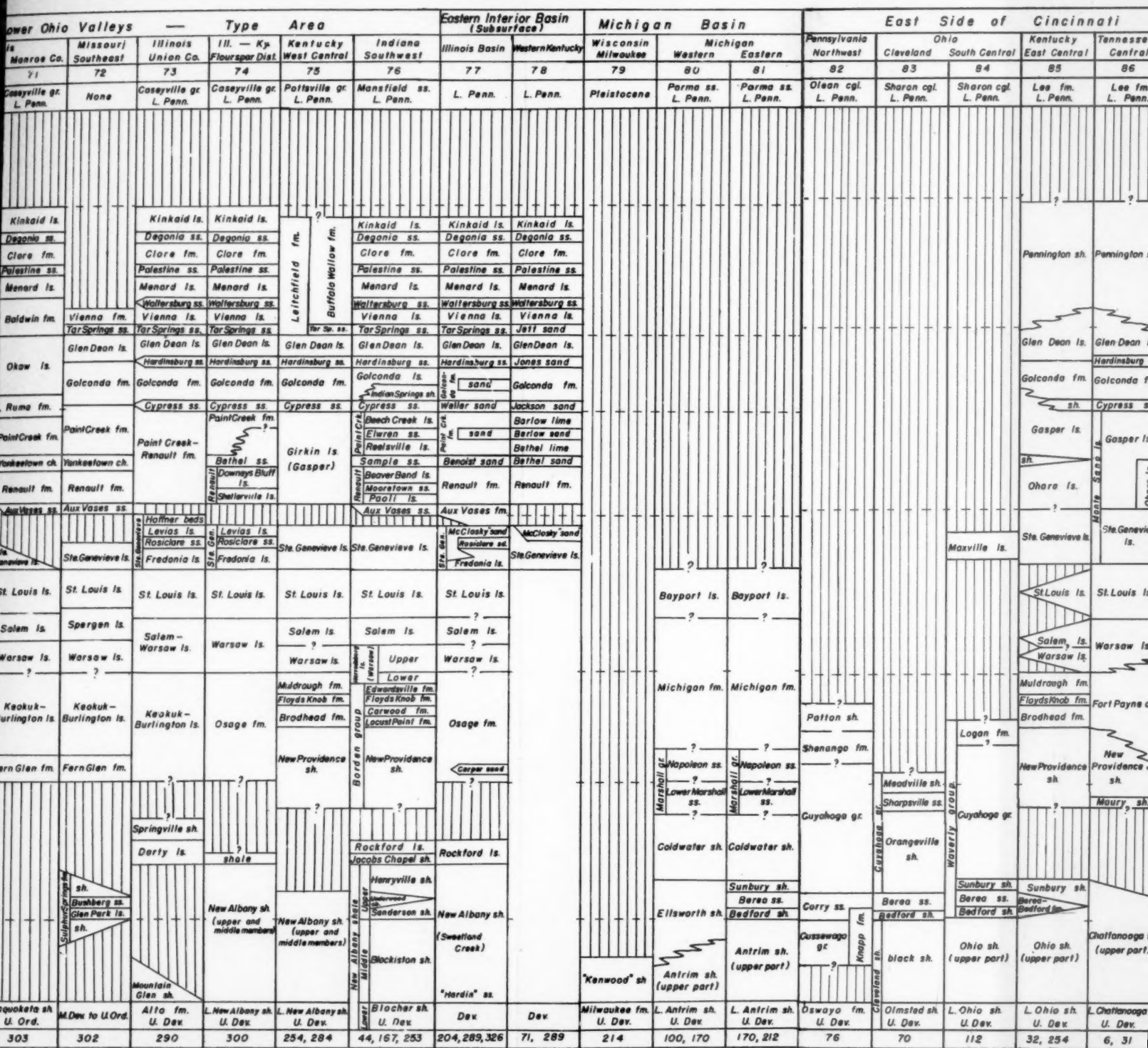
ISSISSIPPIAN FORMATIONS OF NORTH AMERICA

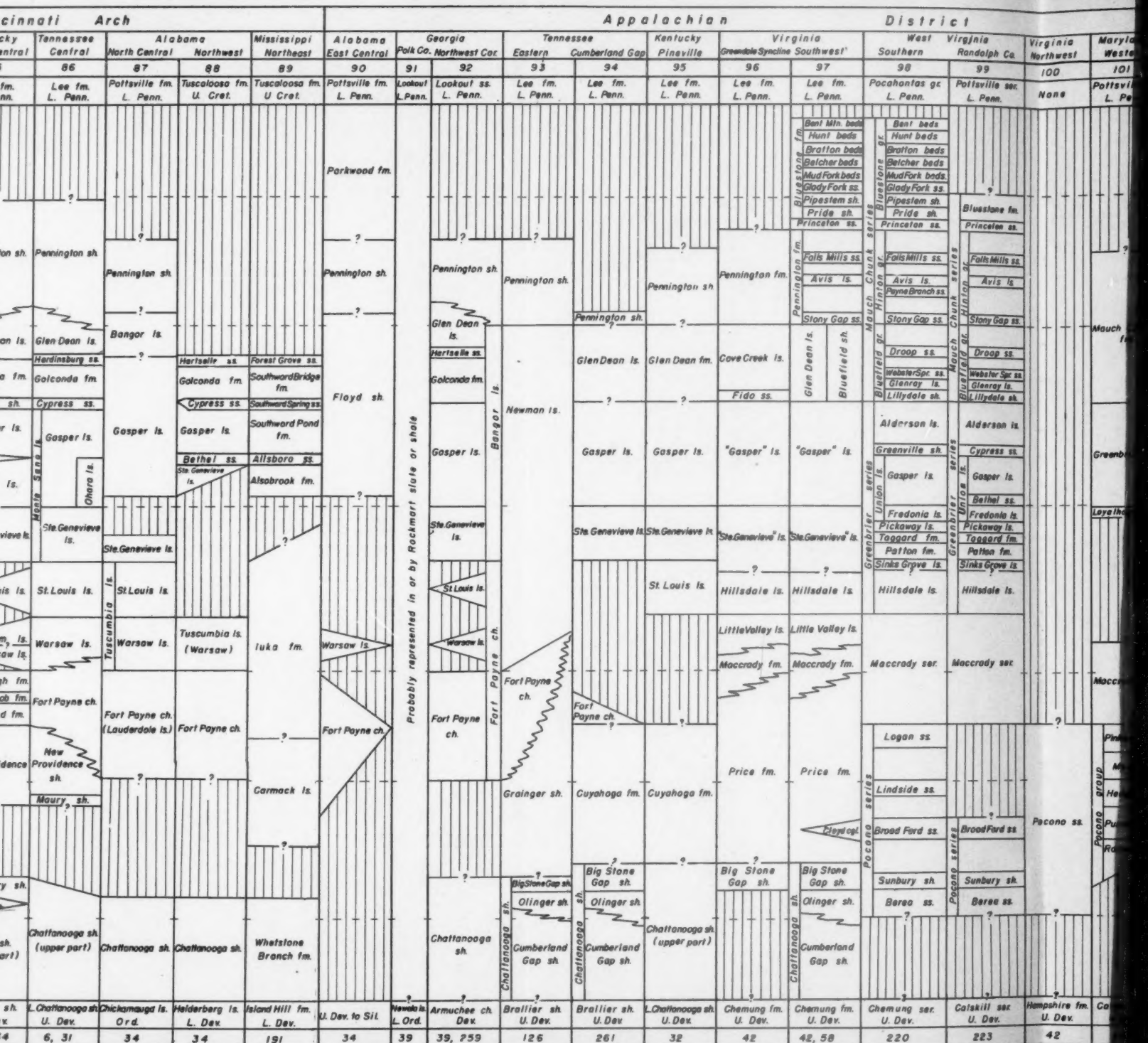
C. Moore, Paris B. Stockdale, P. S. Warren, Kenneth E. Caster, Chalmer L. Cooper, Bradford Willard, Carey Croneis, Clyde A. Malott, Paul H. Price, and A



Price, and A. H. Sutton.




Lower Ohio Valleys — Type Area
Eastern Interior Basin (Subsurface)
Michigan Basin
East Side of Cincinnati
Is Monroe Co.
Missouri Southeast
Illinois Union Co.
Ill. — Ky. Flourspar Dist.
Kentucky West Central
Indiana Southwest
Illinois Basin
Western Kentucky
Wisconsin Milwaukee
Michigan Western
Michigan Eastern
Pennsylvania Northwest
Ohio Cleveland
Ohio South Central
Kentucky East Central
Tennessee Central
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
Caseyville gr. L. Penn.
None
Caseyville gr. L. Penn.
Caseyville gr. L. Penn.
Pottsville gr. L. Penn.
Mansfield ss. L. Penn.
L. Penn.
L. Penn.
Pleistocene
Parma ss. L. Penn.
Parma ss. L. Penn.
Olean cgl. L. Penn.
Sharon cgl. L. Penn.
Sharon cgl. L. Penn.
Lee fm. L. Penn.
Lee fm. L. Penn.
Kinkaid ls.
Degonia ss.
Clore fm.
Palestine ss.
Menard ls.
Waltersburg ss.
Vienna ls.
Tar Springs ss.
Glen Dean ls.
Hardinsburg ss.
Golconda fm.
Cypress ss.
PaintCreek fm.
Yankeetown ch.
Renault fm.
Aux Vases ss.
Ste. Genevieve ls.
St. Louis ls.
Salem ls.
Warsaw ls.
Keokuk–Burlington ls.
Fern Glen fm.
Maquoketa sh.
U. Ord.
303
Vienna fm.
Tar Springs ss.
Spergen ls.
Fern Glen fm.
Sulphur Springs gr.
sh.
Bushberg ss.
Glen Park ls.
sh.
M. Dev. to U. Ord.
302
Kinkaid ls.
Degonia ss.
Clore fm.
Palestine ss.
Menard ls.
Waltersburg ss.
Vienna ls.
Tar Springs ss.
Glen Dean ls.
Hardinsburg ss.
Golconda fm.
Cypress ss.
Paint Creek – Renault fm.
Hoffner beds
Levias ls.
Rosiclare ss.
Fredonia ls.
Salem – Warsaw ls.
Keokuk–Burlington ls.
Springville sh.
Derty ls.
Mountain Glen sh.
Alto fm.
U. Dev.
290
Kinkaid ls.
Degonia ss.
Clore fm.
Palestine ss.
Menard ls.
Waltersburg ss.
Vienna ls.
Tar Springs ss.
Glen Dean ls.
Hardinsburg ss.
Golconda fm.
Cypress ss.
PaintCreek fm.
Bethel ss.
Downeys Bluff ls.
Shetlerville ls.
Renault
Levias ls.
Rosiclare ss.
Fredonia ls.
Ste. Gen.
Warsaw ls.
Osage fm.
shale
New Albany sh. (upper and middle members)
L. New Albany sh.
U. Dev.
300
Leitchfield fm.
Buffalo Wallow fm.
Tar Sp. ss.
Girkin ls. (Gasper)
Ste. Genevieve ls.
Salem ls.
Warsaw ls.
Middlough fm.
Floyds Knob fm.
Brodhead fm.
New Providence sh.
New Albany sh. (upper and middle members)
L. New Albany sh.
U. Dev.
254, 284
Kinkaid ls.
Degonia ss.
Clore fm.
Palestine ss.
Menard ls.
Waltersburg ss.
Vienna ls.
Tar Springs ss.
Glen Dean ls.
Hardinsburg ss.
Golconda ls.
Indian Springs sh.
Cypress ss.
Beech Creek ls.
Elwren ss.
Reelsville ls.
Sample ss.
Beaver Bend ls.
Mooretown ss.
Paoli ls.
Aux Vases ss.
Ste. Genevieve ls.
Salem ls.
Warsaw ls.
Hannibal ls. (Warsaw)
Upper
Lower
Edwardsville fm.
Floyds Knob fm.
Carwood fm.
Locust Point fm.
Borden group
New Providence sh.
Rockford ls.
Jacobs Chapel sh.
Henryville sh.
Lanesville
Sanderson ls.
New Albany shale
Upper
Middle
Lower
Blockiston sh.
Blocher sh.
U. Dev.
44, 167, 253
Kinkaid ls.
Degonia ss.
Clore fm.
Palestine ss.
Menard ls.
Waltersburg ss.
Vienna ls.
Tar Springs ss.
Glen Dean ls.
Hardinsburg ss.
Golconda fm.
sand
Weller sand
Point Creek fm.
sand
Benoist sand
Renault fm.
Aux Vases fm.
McClosky sand
Rosiclare sd.
Fredonia ls.
Ste. Gen.
Ste. Genevieve ls.
Salem ls.
Warsaw ls.
Osage fm.
Carper sand
Rockford ls.
New Albany sh. (Sweetland Creek)
"Hardin" ss.
Dev.
204, 289, 326
Kinkaid ls.
Degonia ss.
Clore fm.
Palestine ss.
Menard ls.
Waltersburg ss.
Vienna ls.
Tar Springs ss.
Jett sand
Glen Dean ls.
Jones sand
Golconda fm.
Jackson sand
Barlow lime
Barlow sand
Bethel lime
Bethel sand
Renault fm.
McClosky sand
Ste. Genevieve ls.
Dev.
71, 289
"Kenwood" sh
Milwaukee fm.
U. Dev.
214
Bayport ls.
Michigan fm.
Marshall gr.
Napoleon ss.
Lower Marshall ss.
Coldwater sh.
Ellsworth sh.
Antrim sh. (upper part)
L. Antrim sh.
U. Dev.
100, 170
Bayport ls.
Michigan fm.
Marshall gr.
Napoleon ss.
Lower Marshall ss.
Coldwater sh.
Sunbury sh.
Berea ss.
Bedford sh.
Antrim sh. (upper part)
L. Antrim sh.
U. Dev.
170, 212
Patton sh.
Shenango fm.
Cuyahoga gr.
Corry ss.
Cussewago gr.
Knapp fm.
Cleveland sh.
Oswayo fm.
U. Dev.
76
Meadville sh.
Sharpsville ss.
Cuyahoga gr.
Orangeville sh.
Berea ss.
Bedford sh.
black sh.
Olmsted sh.
U. Dev.
70
Maxville ls.
Logan fm.
Cuyahoga gr.
Waverly group
Sunbury sh.
Berea ss.
Bedford sh.
Ohio sh. (upper part)
L. Ohio sh.
U. Dev.
112
Pennington sh.
Glen Dean ls.
Golconda fm.
sh.
Gasper ls.
sh.
Ohara ls.
Ste. Genevieve ls.
St. Louis ls.
Salem ls.
Warsaw ls.
Muldraugh fm.
Floyds Knob fm.
Brodhead fm.
New Providence sh.
Sunbury sh.
Berea ss.
Bedford sh.
Ohio sh. (upper part)
L. Ohio sh.
U. Dev.
32, 254
Pennington
Glen Dean
Hardinsburg
Golconda f
Cypress s
Gasper ls.
Main Sand ls.
Ste. Genevie ls.
St. Louis l
Warsaw ls.
Fort Payne
New Providence sh.
Maury sh.
Chattanooga (upper part)
L. Chattanooga
U. Dev.
6, 31


Cincinnati Arch
Appalachian District
Tennessee Central
Alabama North Central
Alabama Northwest
Mississippi Northeast
Alabama East Central
Georgia Polk Co.
Georgia Northwest Cor.
Tennessee Eastern
Tennessee Cumberland Gap
Kentucky Pineville
Virginia Greendale Syncline
Virginia Southwest
West Virginia Southern
Virginia Randolph Co.
Virginia Northwestern
Maryland Western
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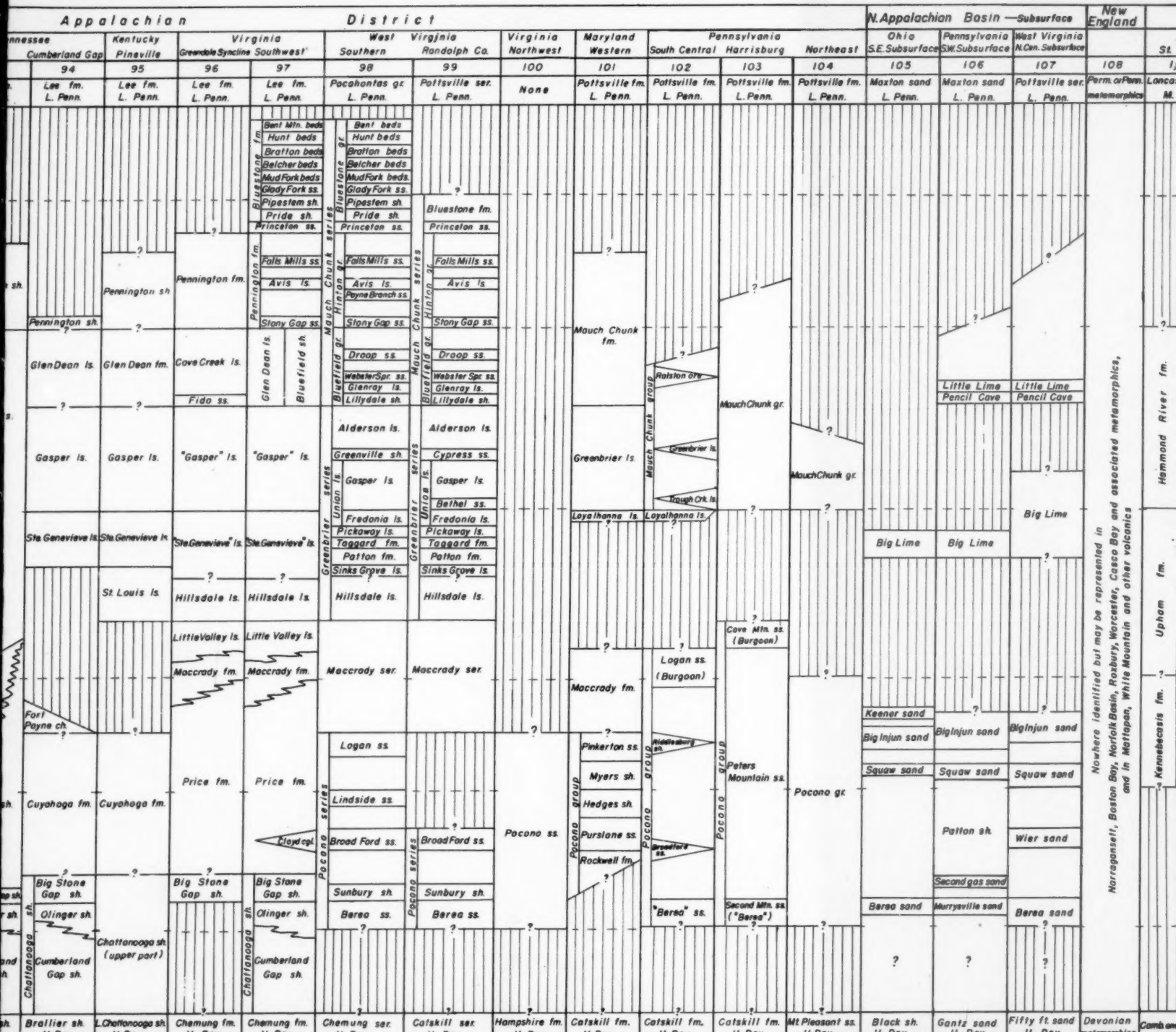
99
100
101
Lee fm. L. Penn.
Pottsville fm. L. Penn.
Tuscaloosa fm. U. Cret.
Tuscaloosa fm. U Cret.
Pottsville fm. L. Penn.
Lookout L. Penn.
Lookout ss. L. Penn.
Lee fm. L. Penn.
Lee fm. L. Penn.
Lee fm. L. Penn.
Lee fm. L. Penn.
Lee fm. L. Penn.
Pocahontas gr. L. Penn.
Pottsville ser. L. Penn.
None
Pottsville L. Penn.
Pennington sh.
Parkwood fm.
Pennington sh.
Floyd sh.
Probably represented in or by Rockmart slate or shale
Pennington sh.
Glen Dean ls.
Hartselle ss.
Golconda fm.
Bangor ls.
Gasper ls.
Ste. Genevieve ls.
Fort Payne ch.
Newman ls.
Grainger sh.
Chattanooga sh.
Cumberland Gap sh.
Big Stone Gap sh.
Olinger sh.
Pennington fm.
Bluestone fm.
Princeton ss.
Mauch Chunk series
Hinton gr.
Bluefield gr.
Falls Mills ss.
Avis ls.
Payne Branch ss.
Stony Gap ss.
Droop ss.
Webster Spr. ss.
Glenray ls.
Lillydale sh.
Greenbrier series
Alderson ls.
Greenville sh.
Union ls.
Gasper ls.
Bethel ss.
Fredonia ls.
Pickaway ls.
Taggard fm.
Patton fm.
Sinks Grove ls.
Hillsdale ls.
Maccrady ser.
Pocono series
Logan ss.
Lindside ss.
Broad Ford ss.
Sunbury sh.
Berea ss.
Pocono ss.
Pocono group
Glen Dean fm.
Cove Creek ls.
Fido ss.
Glen Dean ls.
Bluefield sh.
"Gasper" ls.
Ste. Genevieve ls.
St. Louis ls.
Little Valley ls.
Price fm.
Cloyd cgl.
Big Stone Gap sh.
Olinger sh.
Chattanooga sh.
Cumberland Gap sh.
Monte Sano ls.
Ohara ls.
Tuscumbia ls.
St. Louis ls.
Warsaw ls.
Fort Payne ch.
New Providence sh.
Maury sh.
Chattanooga sh. (upper part)
Tuscumbia ls. (Warsaw)
Fort Payne ch. (Lauderdale ls.)
Carmack ls.
Whetstone Branch fm.
Forest Grove ss.
Southward Bridge fm.
Southward Spring ss.
Southward Pond fm.
Allsboro ss.
Alsobrook fm.
Ste. Genevieve ls.
Ste. Genevieve ls.
Fort Payne ch.
Warsaw ls.
Fort Payne ch.
Fort Payne ch.
Fort Payne ch


Appalachian District
N. Appalachian Basin — Subsurface
New England
Tennessee
Cumberland Gap
Kentucky
Pineville
Virginia
Greendale Syncline
Southwest
West
Southern
Virginia
Randolph Co.
Virginia
Northwest
Maryland
Western
Pennsylvania
South Central
Harrisburg
Northeast
Ohio
S.E. Subsurface
Pennsylvania
S.W. Subsurface
West Virginia
N. Con. Subsurface
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Lee fm.
L. Penn.
Pennington sh.
Glen Dean ls.
Gasper ls.
Sta. Genevieve ls.
St. Louis ls.
Cuyahoga fm.
Big Stone Gap sh.
Olinger sh.
Cumberland Gap sh.
Bratlier sh.
U. Dev.
261
Lee fm.
L. Penn.
Pennington sh.
Glen Dean fm.
Gasper ls.
Sta. Genevieve ls.
St. Louis ls.
Cuyahoga fm.
Chattanooga sh. (upper part)
L. Chattanooga sh.
U. Dev.
32
Lee fm.
L. Penn.
Pennington fm.
Cove Creek ls.
Fido ss.
"Gasper" ls.
"Ste Genevieve" ls.
Hillsdale ls.
Little Valley ls.
Maccrady fm.
Price fm.
Big Stone Gap sh.
Olinger sh.
Chattanooga sh.
Cumberland Gap sh.
Chemung fm.
U. Dev.
42
Lee fm.
L. Penn.
Bent Mtn. beds
Hunt beds
Bratton beds
Belcher beds
Mud Fork beds
Glady Fork ss.
Pipestem sh.
Pride sh.
Princeton ss.
Pennington fm.
Falls Mills ss.
Avis ls.
Stony Gap ss.
Glen Dean ls.
Bluefield sh.
"Gasper" ls.
"Ste Genevieve" ls.
Hillsdale ls.
Little Valley ls.
Maccrady fm.
Price fm.
Cloyd cgl.
Big Stone Gap sh.
Olinger sh.
Chattanooga sh.
Cumberland Gap sh.
Chemung fm.
U. Dev.
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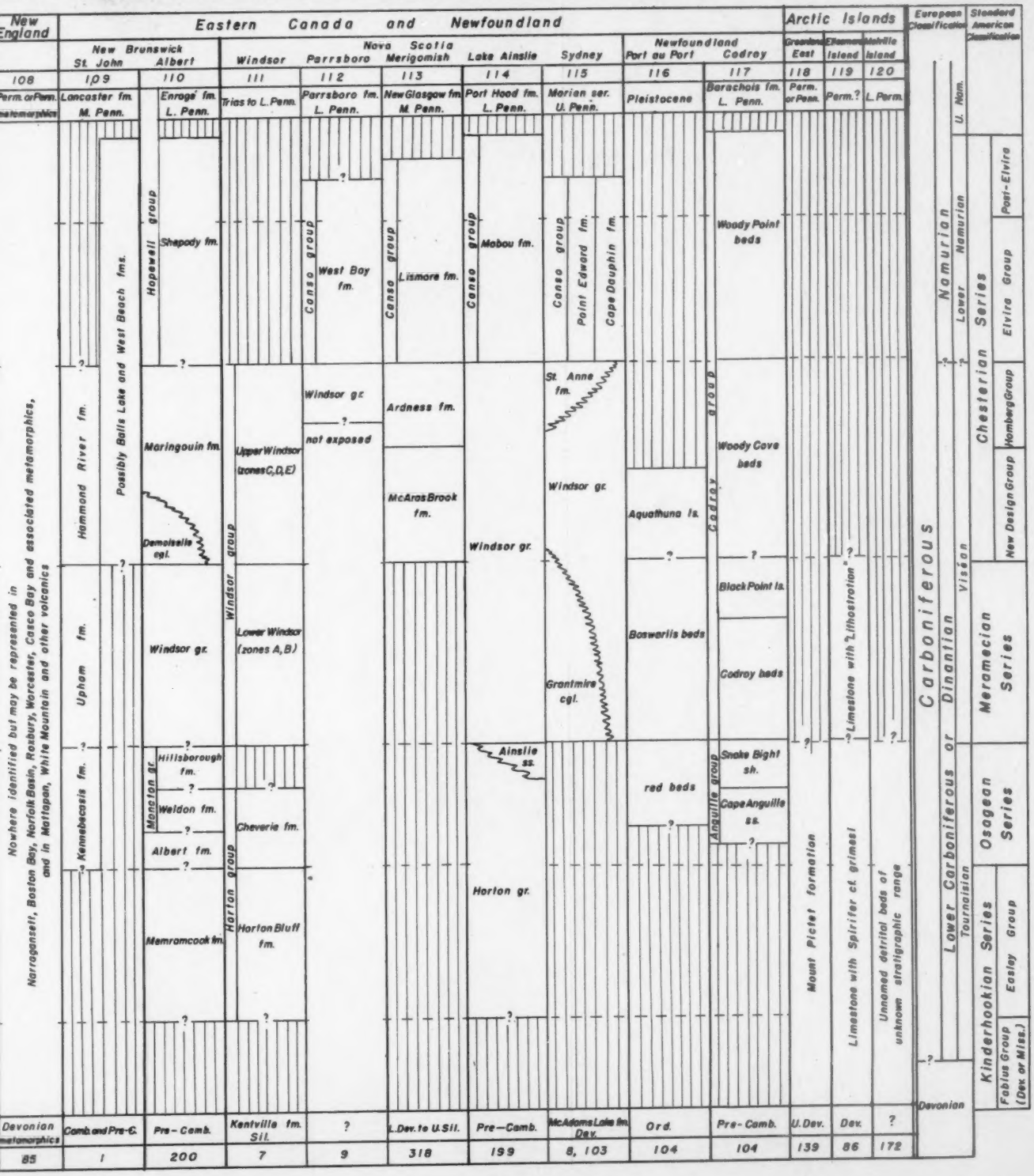
Pocahontas gr.
L. Penn.
Bluestone fm.
Bluestone gr.
Mauch Chunk series
Hinton gr.
Bluefield gr.
Greenbrier series
Pocono series
Bent beds
Hunt beds
Bratton beds
Belcher beds
Mud Fork beds
Glady Fork ss.
Pipestem sh.
Pride sh.
Princeton ss.
Falls Mills ss.
Avis ls.
Payne Branch ss.
Stony Gap ss.
Droop ss.
Webster Spr. ss.
Glenray ls.
Lillydale sh.
Alderson ls.
Greenville sh.
Union ls.
Gasper ls.
Fredonia ls.
Pickaway ls.
Taggard fm.
Patton fm.
Sinks Grove ls.
Hillsdale ls.
Maccrady ser.
Logan ss.
Lindside ss.
Broad Ford ss.
Sunbury sh.
Berea ss.
Chemung ser.
U. Dev.
220
Pottsville ser.
L. Penn.
Bluestone fm.
Princeton ss.
Falls Mills ss.
Avis ls.
Stony Gap ss.
Droop ss.
Webster Spr. ss.
Glenray ls.
Lillydale sh.
Alderson ls.
Cypress ss.
Gasper ls.
Bethel ss.
Fredonia ls.
Pickaway ls.
Taggard fm.
Patton fm.
Sinks Grove ls.
Hillsdale ls.
Maccrady ser.
Broad Ford ss.
Sunbury sh.
Berea ss.
Catskill ser.
U. Dev.
223
None
Pocono ss.
Hampshire fm.
U. Dev.
42
Pottsville fm.
L. Penn.
Mauch Chunk fm.
Greenbrier ls.
Loyalhanna ls.
Maccrady fm.
Pinkerton ss.
Myers sh.
Hedges sh.
Pursglane ss.
Rockwell fm.
Pocono group
Catskill fm.
U. Dev.
255
Pottsville fm.
L. Penn.
Raistón ore
Greenbrier ls.
Trough Crk. ls.
Loyalhanna ls.
Logan ss. (Burgoon)
Maccrady fm.
Middlesboro sh.
Greenbrier ss.
"Berea" ss.
Catskill fm.
U. Dev.
221
Pottsville fm.
L. Penn.
Mauch Chunk gr.
Cove Mtn. ss. (Burgoon)
Peters Mountain ss.
Second Mtn. ss. ("Berea")
Catskill fm.
U. Dev.
311
Pottsville fm.
L. Penn.
Mauch Chunk gr.
Pocono gr.
Mt. Pleasant ss.
U. Dev.
313
Maxton sand
L. Penn.
Big Lime
Keener sand
Big Injun sand
Squaw sand
Berea sand
Black sh.
U. Dev.
160, 205
Maxton sand
L. Penn.
Little Lime
Pencil Cave
Big Lime
Big Injun sand
Squaw sand
Patton sh.
Second gas sand
Murrysville sand
Gantz sand
U. Dev.
205, 226
Pottsville ser.
L. Penn.
Little Lime
Pencil Cave
Big Lime
Big Injun sand
Squaw sand
Wier sand
Berea sand
Fifty ft. sand
U. Dev.
205, 222
Perm. or Penn. metamorphics
Nowhere identified but may be represented in Narragansett, Boston Bay, Norfolk Basin, Roxbury, Worcester, Casco Bay and associated metamorphics, and in Mattapan, White Mountain and other volcanics
Devonian metamorphics
85
Lancas
M.
Hammond River fm.
Upham fm.
Kennebecasis fm.
Comb. an

under the auspices of the Committee on Stratigraphy of the National Research Council, Carl O. Dunbar, Chairman



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Italics—Partially or doubtfully Mississippian units
Roman type—Non-Mississippian units

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Abbreviations: cgl., conglomerate; ch., chert; dol., dolomite; fac., facies; fm., formation; gr., group; ls., limestone; mem., member; qtz., quartzite; ser., series; sh., shale; slt., siltstone., ss., sandstone.

AINSLIE SS. 175; II 114.
ALAMAGORDO LS. 142; II 50.
ALBERT FM. 174; II 110.
ALDEN LS. 101, 150.
ALDERSON LS. II 98, 99.
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ALSOBROOK FM. II 89.
Alto fm. II 73.
Amsden fm. 139, 140, 141; II 39, 40, 44.
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ANCHOR LS. II 23.
ANGUILLE SER. 176; II 117.
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BAIRD SH. 132; II 13.
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Balls Lake fm. II 109.
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